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The University of Michigan
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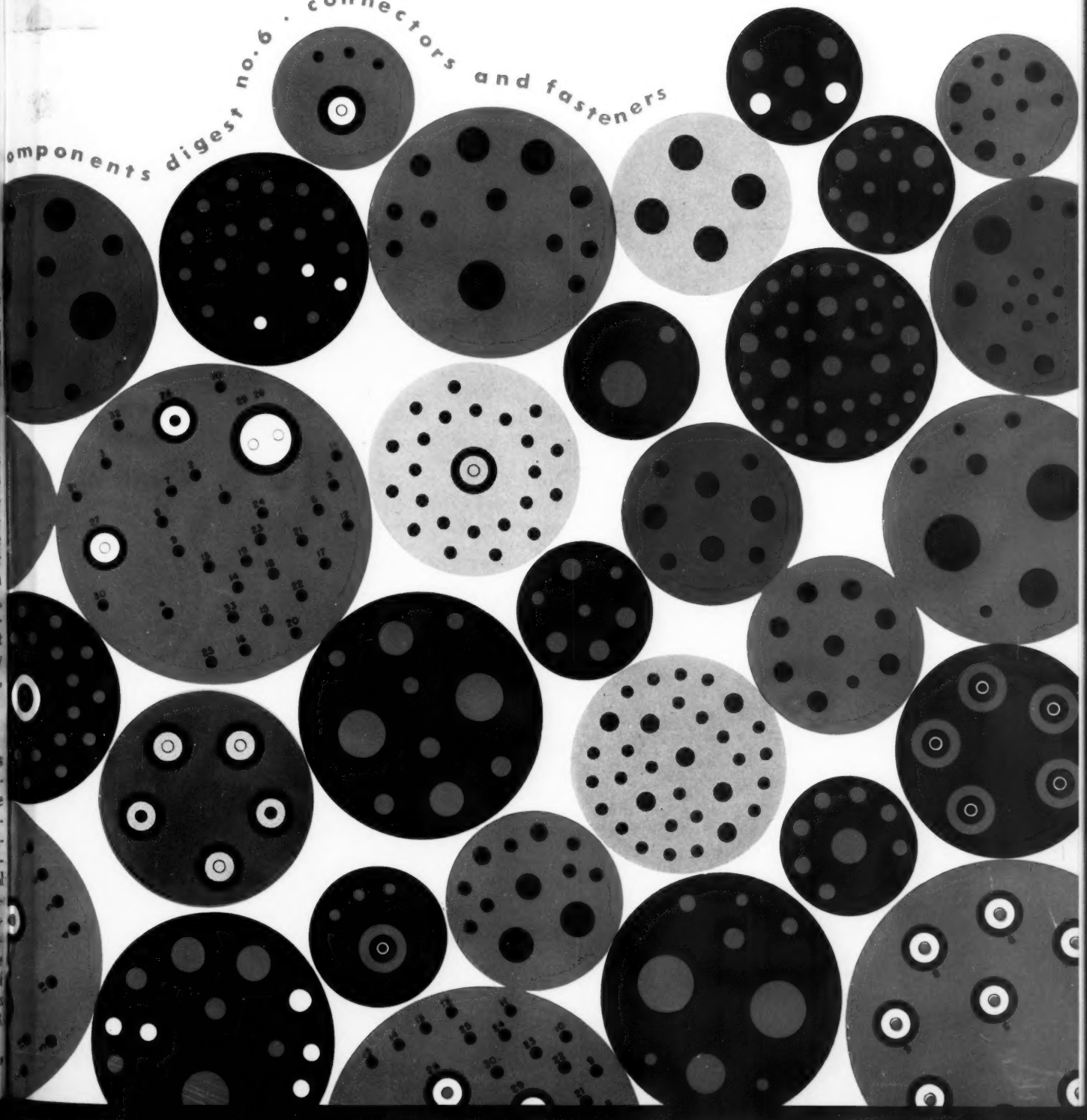
ELECTROMECHANICAL components & systems DESIGN

may 1959

components digest no. 6 . connectors and fasteners



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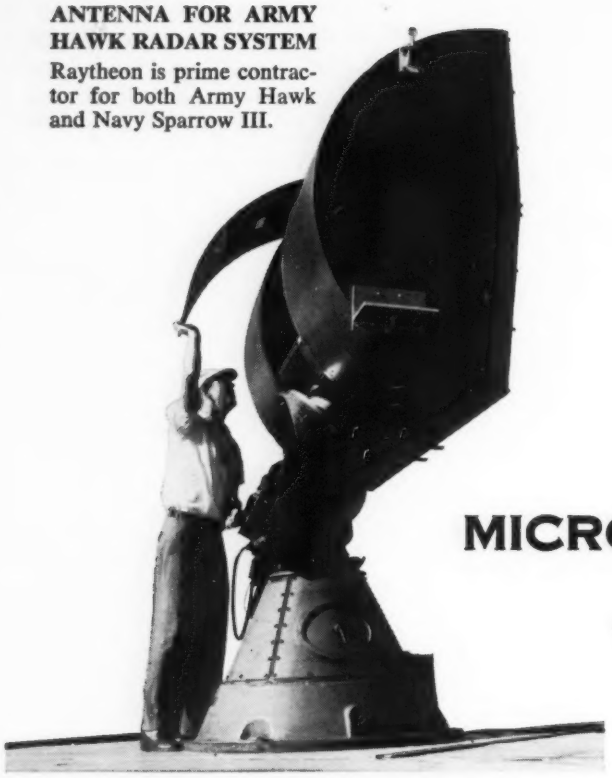

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VOL. 3, NO. 5

MAY 1959

ELECTROMECHANICAL components & systems DESIGN

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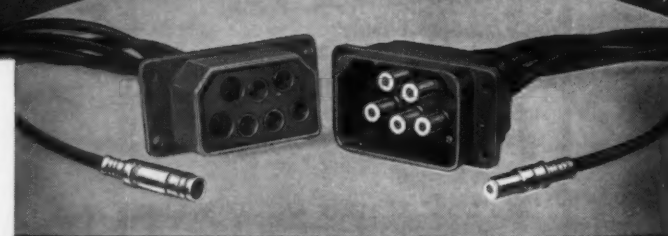

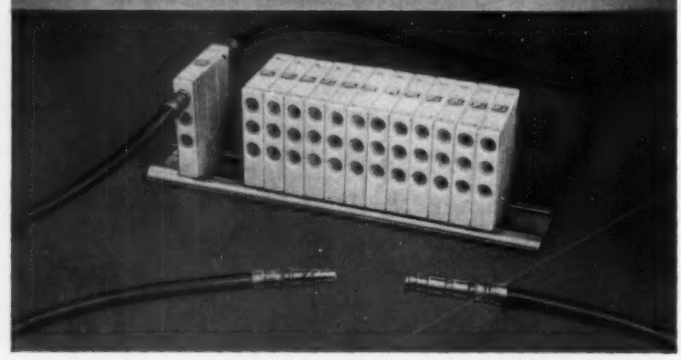

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WANTED: Creative Engineers

A quick glance at "help wanted" sections of large metropolitan newspapers reveals that many companies are looking for electromechanical engineers with creative ability for highly responsible positions. Industry is recognizing the need for men with broad science and engineering background to carry out the complex development programs now in demand.

Many companies prefer to train engineering scientists in special skills required for a job rather than to rely on engineers trained for the job at hand but limited to those scientific and engineering disciplines sufficient to understanding the present state of their art. The state of any important art will take new directions involving new principles and devices. Narrow specialists may be able to follow the new developments but they are less likely to lead them. Broad understanding of scientific concepts and principles and wide knowledge of devices and techniques are instrumental in creative engineering. They are the material for the imagination.

But science and engineering training although important are not sufficient factors for creative engineering. Recognizing the importance of this subject, ELECTROMECHANICAL DESIGN has been publishing columns by Professor A. H. Maslow of Brandeis University on the very subtle psychological factors that underlie creativity. Next month's issue will include the final part of his column on "Creativity in Self-Actualizing People" in which he stresses personal qualities such as "boldness, courage, freedom, spontaneity, perspicuity, integration and self-acceptance" that underlie the creative attitude. Then starting with the July issue and continuing monthly we will publish a series of columns by Hymen Olken of the University of California Radiation Lab constituting a course in the art of inventing. The introduction to this series was published in our February issue. Mr. Olken says "large scale development projects such as weapon systems, must be carried out by team effort. But the creative capacity of the team is basically determined by the creative ability of the individuals who compose it." Mr. Olken proposes a training program whereby engineers and scientists can educate themselves to increase their creative ability. Concrete illustrations from industry will be given, with special emphasis on the fields of electromechanics and electronics.

NEW SCHEDULE

The Components Digest series scheduled as monthly supplements in ELECTROMECHANICAL DESIGN is based on information received in response to questionnaires sent to all known American manufacturers of the equipments being covered. The response of these companies has been so overwhelming we cannot do justice to the important information received within the schedule originally announced in our December issue. Rather than to reduce our proposed objectives for this series, we prefer to reschedule the insertions. Accordingly, here is the schedule for future issues.

June—Analog-Digital Converters, Part I
Environmental Design & Testing, Part II
July—Connectors & Fasteners, Part II
Analog-Digital Converters, Part II
August—Switches, Part I
September—Fractional Horsepower Motors
October—Switches, Part II
November—Sub System Packages
December—High Temperature Components

Recorders and Indicators and Vehicle Reference Systems will be scheduled early in 1960.

Robert B. Brotherston

EDITOR

ELECTRICAL PATCH PANEL

Quick Connect-Disconnect for Missile Fire Control

Missile fire control systems call for patch panel designs that permit large number of connections to be quickly connected—under combat conditions—and then quickly disconnected for connection to another location. Engineers at E. B. Wiggins Oil Tool Company, Los Angeles, California, have come up with a design that permits quick connect-disconnect to a patch panel consisting of three rows of 16 vertical sockets, each socket containing 150 connectors (Fig. 1).

Connections can be made from any one of the 48 positions to any other one—in a hurry. In addition, any one of the vertical columns can be removed and put on another panel.

Wiggins' design is based on a spring loaded latching mechanism. Individual patch cord nipples contain an index pin which is the center pin of 3 pins on each side of the socket. The index pin is engaged in its socket, the assembly is racked downward so that the bottom pin engages under the latch; then the assembly is racked upward to engage the pin at the top of the socket. The entire socket releases by grasping the cable connection and pressing the individual disconnect lever, popping the entire unit into the operator's hand.

Popping action is supplied by the three-leaf spring connectors that make and break the electrical circuit. One-hundred and fifty low force springs are put under compression when the patch cord is indexed and racked into position. Releasing the latch causes the assembly to pop-off under a wiping action of the springs. During the pop-off, the wiping action gives a good electrical disconnect, preventing arcing. Spring leafs are phosphor-bronze contact-pins plated with a noble metal for desired electrical characteristics.

Wiggins has designed a number of electrical connectors based on the three-spring, phosphor bronze leaf, as illustrated in the diagrams.

Circle No. 118 on Inquiry Card.

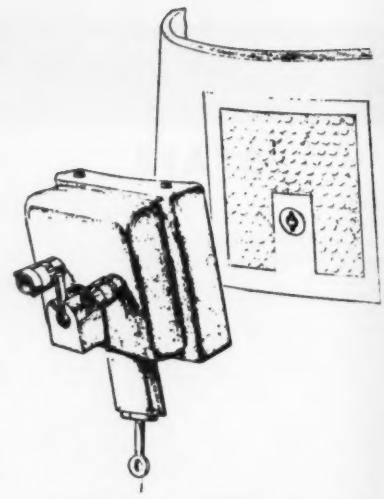
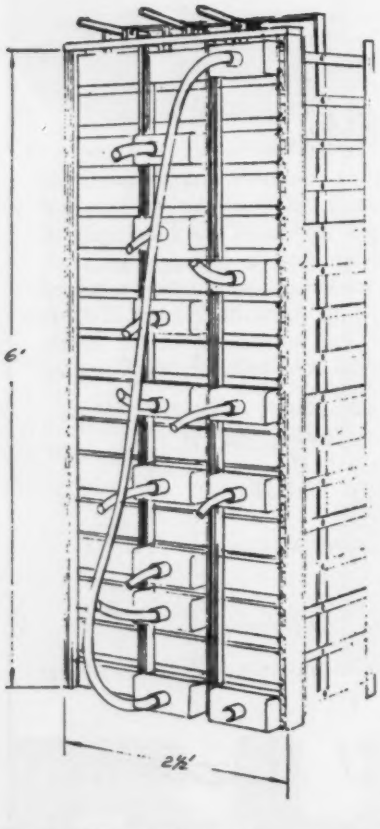


Fig 2 Wiggins' engineers have applied the shear pin action to remote-umbilical connectors. Above illustrates a 250 pin unit for aerodynamically-flush airborne mounting applications.



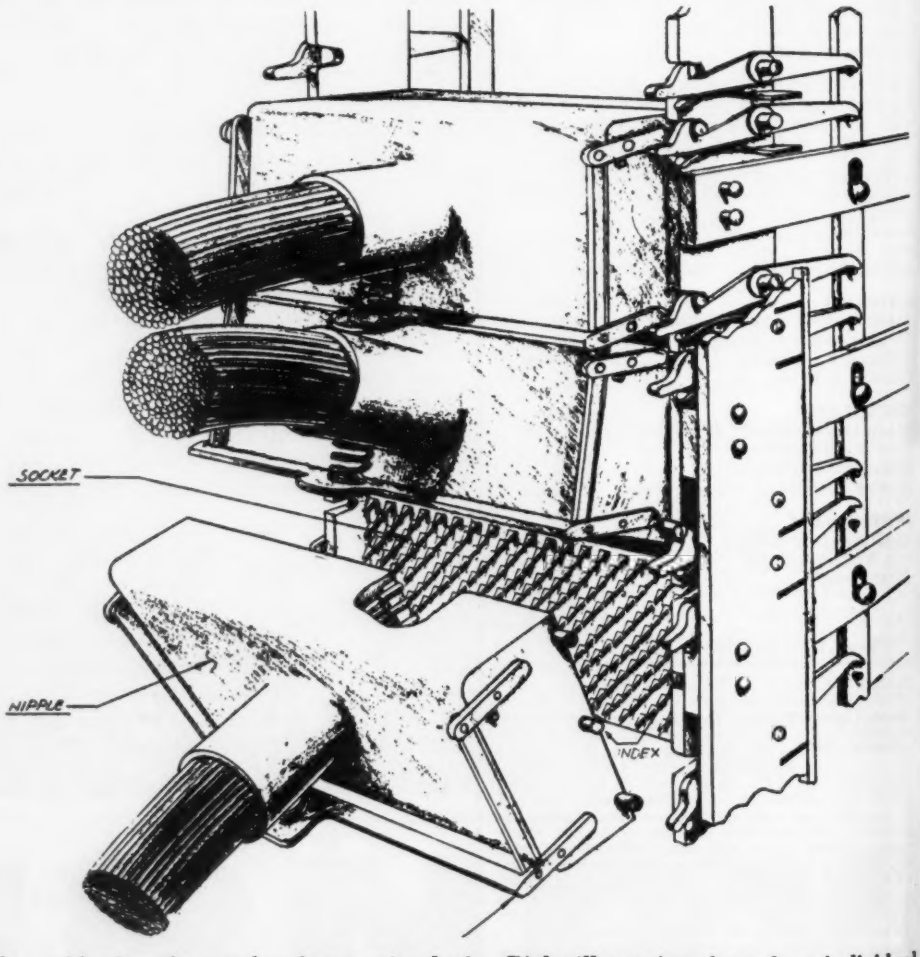


Fig 1 Electrical patch panel with emergency disconnection feature incorporates 150 contacts per connection with pins of a new low force spring leaf design. Release lever (top left) permits entire row of 16 sockets to be removed. Right illustration shows how individual patch cord is connected or disconnected without affecting other 15.

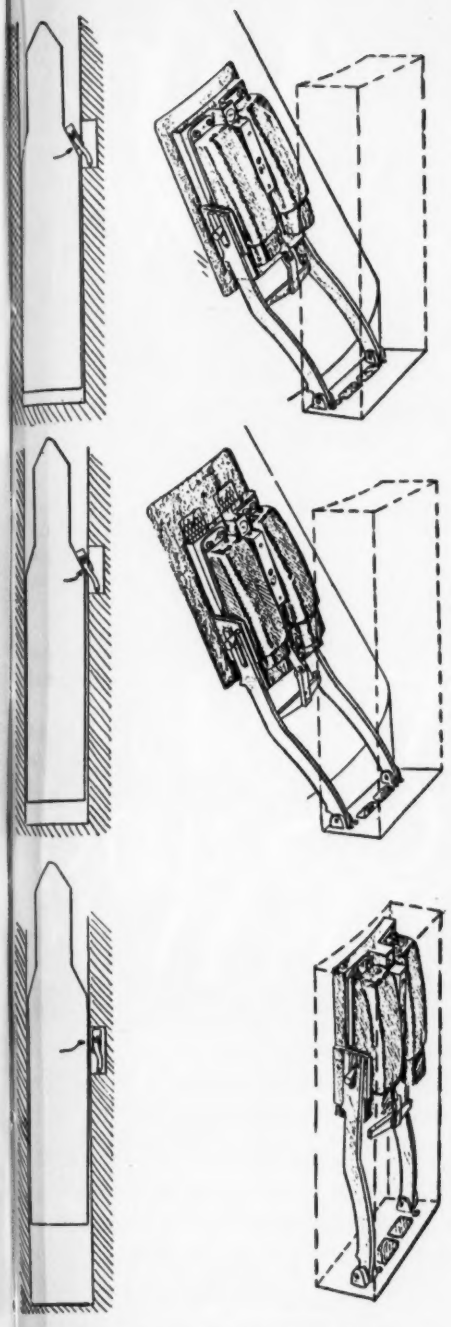


Fig 3 For missile launchings, top illustration shows the connector attached prior to launching. In the middle diagram, the nipple has started its upward travel and the connector has started to disconnect (note shearing action). In the bottom, the connector has sheared free and has retracted into its cavity with the assistance of an umbilical retract mechanism.

Varactors

Twelve-page booklet on Varactors discusses dynamic communications breakthroughs. It gives comprehensive treatment of varactor diodes and negative resistance parametric amplifiers (Harris Amplifiers), and the solid-state physics associated with them.

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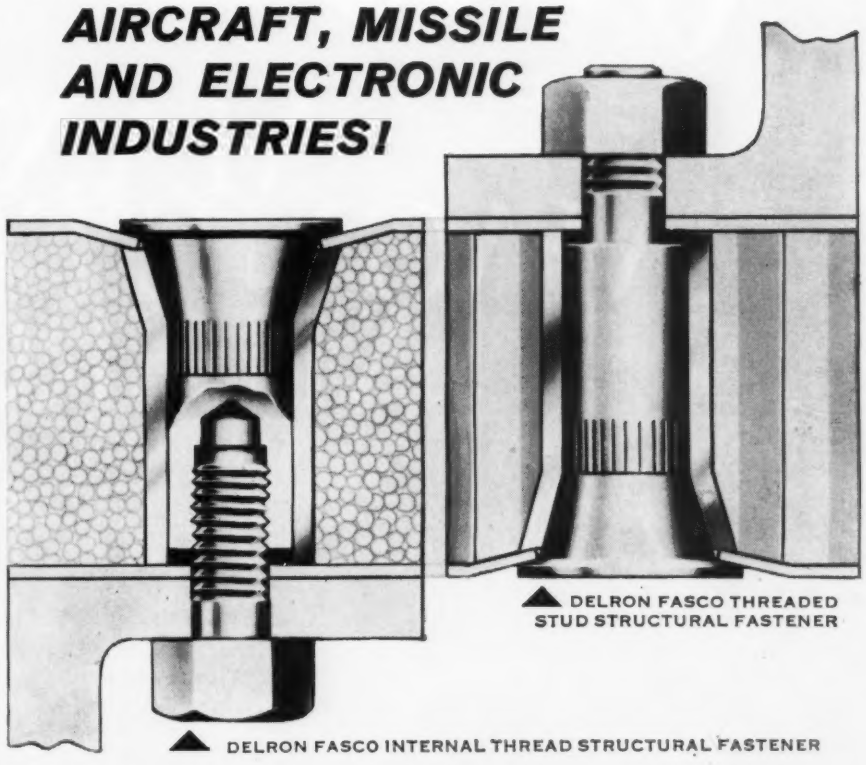

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MISSILE COMPONENTS TESTING

From Test Stand to Dial-A-Circuit "Go-No Go" Simulator

Test equipment required by today's missile industry concerns itself with a new concept of reliability, one which differs significantly from that developed for overhaul and maintenance of aircraft components and systems. Aircraft test equipment performs basically an overhaul function requiring low cost and multi-functioned test machines operated by skilled technicians who have the last word in value judgments.

Missile component testing requires an exchange system, with every component being given a quick, reliable "go-no go" test prior to installation. A missile cannot be "down" for testing—even for a short time.

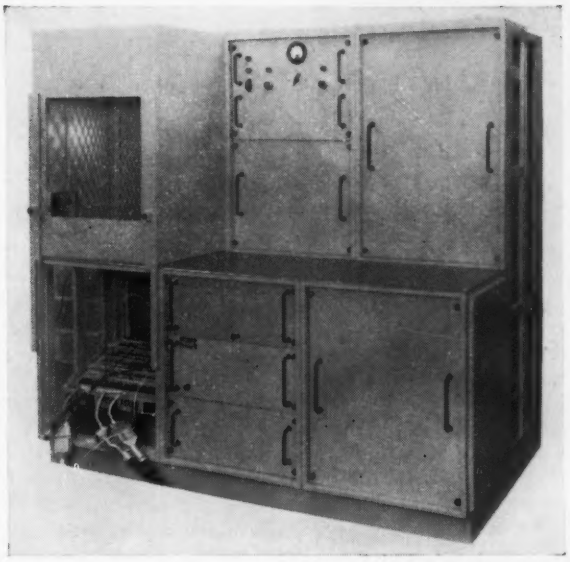
Greer Hydraulics, Inc. engineers have designed a versatile, compact "specific purpose" test machine, operated by one man, that tests all the pneumatic components used on a particular missile in conformance with the stated logistical problems of the missile. Design objectives included:

- one machine to test all components having similar input requirements and output measuring requirements;
- the machine gives a "go or no-go" test result only—possibly, if it didn't complicate the machine or destroy the operator's confidence in the test machine, the machine might also indicate a reject high or a reject low, thereby indicating the direction of deviation from calibration;
- operators only trained to "plug in" the test component and have no value judgment to make.

TEST CIRCUITRY

To accomplish these objectives, Murray Benett, Greer's Weapon System Engineering Group Manager, pointed out that a review of the circuitry required to test various missile components required the following categories of inputs and outputs:

- A source of regulated static pressures for actuation of such components as pressure switches. In addition to the static actuation pressure an electrical read out circuit to read the output of the pressure switch.
- A static test pressure for such components as check valves, burst disc relief valves, etc. which hold pressure but which may not necessarily call for flow. These components would, in turn, be checked for leakage while operating under pressure calling for leakage measuring circuits.
- Circuit design that would test some components under a given input and leakage measured as an output under one condition; and then followed by a second test where the output pressure increases or changes with flow increasing from zero to some value up to full flow would be experienced with a relief valve, regulator or pilot operated valve.



Test set automatically "go-no go" tests twenty-two components under thirty-four different testing conditions. It requires a 2,000 psi clean air input (10 SCFM), 110 volt (5 amp) a-c power supply and occupies a total floor area of 24 square feet. Designed for the Farnsworth Electronics Co., Div. of I.T.T., it tests pneumatic components used in the Bomarc missile. Enclosure and hardware conform as closely as possible to all the other test equipment (including electronics on the Bomarc).

Figures 2, 3 and 4 illustrate that portion of the test circuit for a component required to have a flow of 3 SCFM plus or minus 0.25 SCFM when supplied with an upstream pressure of 50 psi. Assume that this is equivalent to selector switch position number 3. Then, selector switch position 3 energizes the solenoid valve which controls the output from the 50 psi regulator (left-hand side of block diagram), and at the same time, it energizes the solenoid valve which would open the read-out circuit to the 3 SCFM flow measuring device. The flow measuring device is a fixed orifice requiring a given pressure drop across it when passing 3 SCFM. Two pressure switches do the actual read-out, one pressure switch would be set at 3 SCFM minus 0.25 SCFM and the other pressure switch would be set at 3 SCFM plus 0.25 SCFM. If the component is acceptable, only the first pressure switch or only the second pressure switch is energized. If neither pressure switch energizes, the meter indicates "reject low". If both pressure switches energize, the meter indicates "reject high."

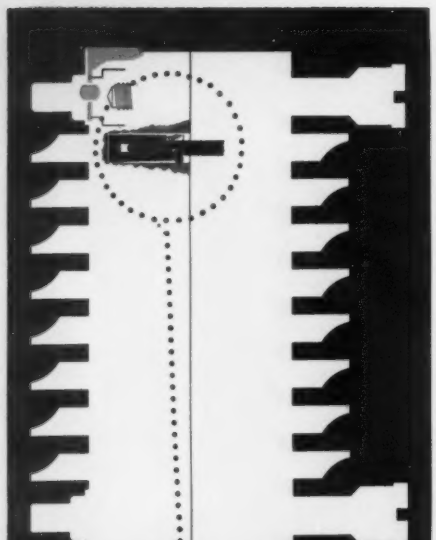
SELF-CHECK CIRCUIT

In addition to the above mentioned differences, Mr. Benett pointed out the advantages of having a self-check circuit designed into the test stand. Prior to performing any component test an operator can check the test set itself by pressing the self test button while in the given switch position. The circuitry required to simulate the test would be a fixed orifice that would flow 3 SCFM when supplied with 50 psi. Input and output of this component simulator would, in turn, be controlled by solenoid valves which would be actuated when the self test push button was pressed and the selector switch was in the proper position. The "accept-reject" meter gives the indication during self-check. The self-check circuit requires that every component used in test be checked during self-check. If all values are correct and all components are operating, the unit will show an accept. If any component does not function or any fixed orifice drifts in value then a reject signal will appear.

CIRCUIT DESIGN

The electrical design in such a system as described above is subservient to the pneumatic requirements. Different pneumatic inputs must be triggered or sequenced either on a time basis or as a result of a previous action, such as a pressure switch being energized. The system itself has certain pneumatic dynamic response characteristics. For example, a definite time lag exists be-

←CIRCLE 7 ON INQUIRY CARD



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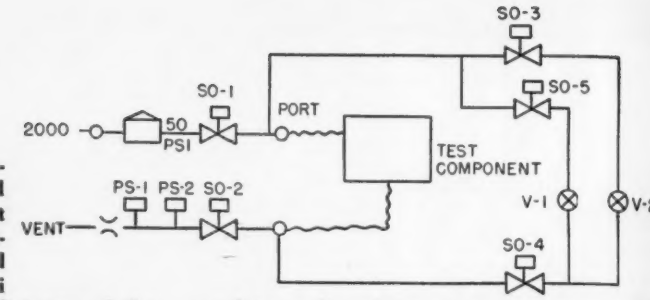
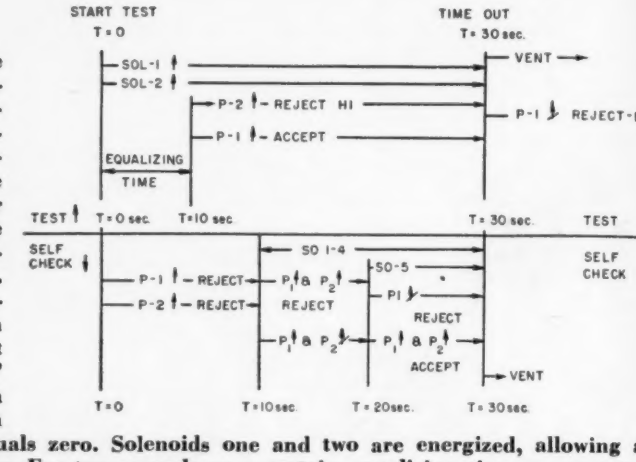
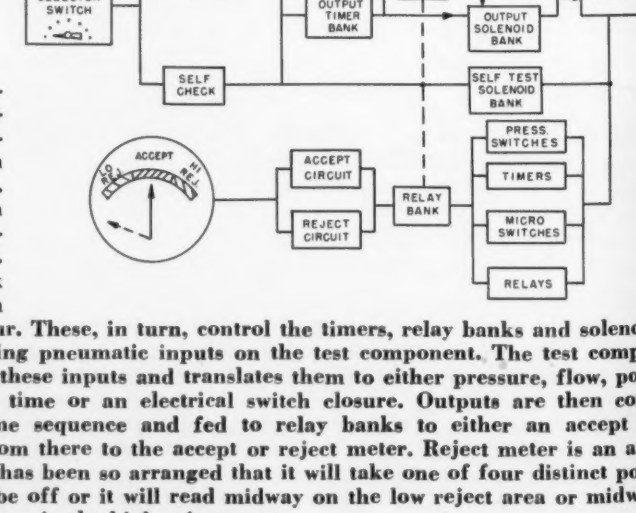


Block form arrangement of the internal circuitry with the test set indicate the various inputs derived from one 2000 psi supply air source. Outputs of these regulators all end up at one or more ports within the safety chamber. Right-hand side shows read-out circuits that measure leakage, flow, pressure, position, etc., resulting from the components.



Electrical sequence criteria chart is composed of 2 parts: upper part is the sequence criteria required during the self-check; lower half is the sequence criteria required during the self-check. Circuit tests a component requiring an output of 3 SCFM at 50 psi. "Start test" is the point at which the start test button is pressed; time equals zero. Solenoids one and two are energized, allowing air and pressure to flow. For ten seconds or a certain equalizing time no accept or reject criteria is recorded in the system. At the end of time equals ten seconds, an accept and reject criteria is established. The third line shows that if pressure switch 2 is energized, a reject high signal results. Line 4 shows that if PS-2 is not energized and PS-1 is energized, an accept condition results. At time equals 30 seconds, the end of the test, if neither pressure switch has been energized, the vent cycle is triggered, venting the entire stand and making it safe to work on. In self-check, between time equals zero and time equals 10 seconds, if neither pressure switch is energized (indicating a stuck pressure switch, since no pressure is applied) a reject condition immediately appears. At time equals 10 seconds, solenoids 1 through 4 are energized. Then, between time equals 10 seconds and time equals 20 seconds, the criteria is that the low pressure switch, P2, shall not be energized. Between time equals 20 seconds and time equals 30 seconds, if a reject condition has not previously occurred, an accept condition occurs if P1 has not been energized. At time equals 20 seconds, solenoid 5 is energized, creating a condition which will cause a reject in ordinary test, that is, pressure switch P2 would be energized, but in self-check this condition must give an accept condition.



Electric block diagram follows a pattern above for problem illustrated in previous diagram. Test selector switch determines which circuits will operate. The test or self-check determines which type of test will occur. These, in turn, control the timers, relay banks and solenoid valves, thereby placing pneumatic inputs on the test component. The test component, in turn, takes these inputs and translates them to either pressure, flow, position or position vs. time or an electrical switch closure. Outputs are then compared against a time sequence and fed to relay banks to either an accept or reject circuit and from there to the accept or reject meter. Reject meter is an ammeter whose circuit has been so arranged that it will take one of four distinct positions. It will either be off or it will read midway on the low reject area or midway in the accept or midway in the high reject area.

tween the time a solenoid valve opens and pressure appears downstream at a test component or at a pressure switch. In addition to these characteristics, the system must have built into it certain accept and reject criteria, such that the test stand will accept or reject at the proper time if the conditions for same are in the proper sequence. In addition, the accept-reject criteria must be reversed during self-check, since all components, including those components which ordinarily reject in a normal test, must be operated to give an "accept" reading in the salf-check circuit.

SPECIAL CONSIDERATIONS

Other special features are:

- Safety chamber door must be closed before a test can be started or pressures applied to the component.
- If the 2000 lb. input air supply fails or if the 110 volt power supply fails, even momentarily, the test will go into an incomplete state with all lights going off, requiring the operator to restart the test to determine the results.
- Regulators, pressure switches, timers and solenoid valves are each in module packages, facilitating assembly insofar as pieces can be subassembled simultaneously externally and then mounted into the small enclosure.
- Design parameters of the components can be readily changed, added to and subtracted.
- To diminish the number of components used, many of them serve a function in more than one test position. The disadvantage of this is that it reduces the versatility of the machine, since these components cannot be changed if only one switch position is affected.

Circle No. 100 on Inquiry Card

Current Probe

Transformer current probe determines the amount of electrical interference a product would cause to radio services by coupling radio frequency noise to a receiver operating over the frequency range of 0.15 mc to 25.0 mc. Requiring no direct or electrical connection to the product being tested, the probe may be used with any calibrated receiver having an input impedance of 50 ohms and reads radio frequency current in the primary in terms of secondary voltage. Insulated to 600 V, the unit may be used on primary conductors carrying up to 350 amperes d.c. or 50 amperes a.c. Stoddart Aircraft Radio Company, Inc., Hollywood, California.

Circle No. 112 on Inquiry Card

New Deutsch "Snap-In" Miniature Connectors

make RELIABILITY a REALITY

Here's a snap-in miniature you can trust to do what it's supposed to do. The new Deutsch DS Series of quick-disconnect connectors—with insertable and removable contacts and crimp-type terminations—has been thoroughly tested and *proved* under extreme environmental conditions.

Check these *proven* advantages against your design requirements

		DS FEATURES	YOUR DESIGN REQUIREMENTS
1	Pins and sockets	Easily insertable and removable	
2	Terminations	Crimp-type	
3	Contact retention	Withstands minimum of 25 lbs. pull	
4	Crimp strength	Greater than the wire itself	
5	Hand tools	Simple, fool-proof crimping, inserting and removal tools	
6	Interfacial seal	Continuous dielectric separation without voids; no bonding, reversion or shrinkage of inserts	
7	Environmental	Meets or exceeds MIL-C-26482 (ASG)	
8	Temperature	—100°F. to 300°F.	
9	Push-pull coupling	Positive ball-lock design; operates in direction of plug travel	
10	Contact size	Immediately available in #20 size; others to follow	
11	Shell size	Immediately available in 3, 7, 12, 19, 27, 37 and 61 contacts	
12	Interchangeability	Mates with existing Deutsch DM5000, DM6500 and DM9000 series	
13	Assembly	Delivered completely assembled except for insertion of contacts	

For complete technical information and test report, contact your Deutsch Representative or write us for Data File 5G.

The Deutsch Company

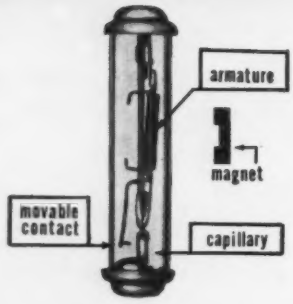
7000 Avalon Boulevard • Los Angeles 3, Calif.

© THE DEUTSCH COMPANY, 1959

CIRCLE 5 ON INQUIRY CARD

NEW miniature encapsulated

"MAGNETIC" MERCURY SWITCH



Actual Size

CAPILLARY TYPE MAGNET OPERATED MERCURY SWITCHES

Moveable contact in the hermetically sealed switch makes contact by penetrating opening in the capillary tube (see illustration). Capillary tube is positioned so as to be supplied by the mercury in the well.

VERY LITTLE POWER REQUIRED TO OPERATE SWITCH

Adaptable to applications where a mechanical movement of approximately 0.007" (minimum) with a force of 2 grams is available to move the permanent magnet. Can be operated by small DC electromagnets for incorporation in electric or electronic equipment.

HIGH SPEED OPERATION

Speeds of 400 cycles per minute (at maximum rated load) are obtainable. Higher speeds are possible depending upon load characteristics.

VARIABLE MOUNTING ANGLE

Operation is possible even if switch is tilted as much as 45° from vertical position.

ELECTRICAL CONNECTIONS

Electrical connections to switch are made through the metallic-end caps, eliminating lead wires attached directly to the switch. They are however, available with lead wires of various lengths.

ELECTRICAL CAPACITY

Type 6-81 normally open and Type 6-83 normally closed.

A.C. 115V., 0.3A.; D.C. 115V., 0.15A.

Write for Bulletin 6-81

THE MERCOID CORPORATION
4201 Belmont Ave., Chicago 41, Ill.

CIRCLE 6 ON INQUIRY CARD

MINIATURE COMPONENTS

Micro-Miniature Relay for Automatic Assembly Techniques

Relays with terminals located on 0.2" x 0.2" coordinates permit mounting on printed circuit boards by automatic assembly techniques. The new terminal layouts are available on both dual coil magnetic latching and on single coil action relays. Both relays operate under 100g shocks and 30g vibrations to 2000 cps with no contact openings in either armature position. Relays with single coil action pull-in at 260 milliwatts at 25C; dual coil latching relays at 230 milliwatts. All coil connections are polarized to take advantage of permanent magnet forces in the relay. Single coil action SCG relays have eight pins located in two rows of four. Magnetic latching SLG relays have ten pins, two located midway between rows. Both units have dpdt contacts rated at 2 amps, 28 volts dc, resistive. Relays are 0.890" high x 0.795" wide x 0.370" thick and weigh less than 20 grams. Potter & Brumfield, Princeton, Ind.

Circle No. 207 on Inquiry Card

Miniaturized Capacitors for Printed Circuitry

A new series of low voltage, space saving capacitors for high temperature environments, transistor circuits and high performance applications have been designed for continuous operation from −70C to 175C without derating. Extended temperature types are available to 200C and 250C respectively without derating. Approximate insulation resistance of the capacitors is: 10^{12}ohms to 125C, 10^{11}ohms to 150C and 10^{10}ohms to 175C. Their temperature coefficient is less than −100PPM/C, power factor is approximately 0.1 percent and absorption less than 0.05 percent. Balco Research Labs., Newark, N.J.

Circle No. 215 on Inquiry Card

Miniaturized Self-Balancing Potentiometer

Highly versatile, miniature flight test instrument, Autopot series EMP-NS2, with dimensions of 3-5/16 x 3-5/16 x 7" accepts outputs from thermocouples or other transducers used in flight test programs. It converts temperature, pressure, stress, flow or acceleration signals into direct-reading indications. Daystrom-Pacific, Los Angeles, Cal.

Circle No. 206 on Inquiry Card

Miniaturized Environment-Free Push-Button Switch

A new sealed push-button switch 40 percent smaller than any other of its type has the same general configuration as sealed switches that conform to MS-25331. Overall dimensions, however, are only ¾" diameter and 1½" high. The push-button stem is threaded for mounting in ½" holes. The operating point may be easily adjusted over a ¼" range by means of lock-nuts on the stem. The switch has high electrical capacity for its size: 6 amps at 125 VAC/30 VDC resistive, 2.5 amps at 30 VDC inductive. Contact arrangement is SPDT. Operating force is 8/12 lbs. plus or minus 3 lbs. which enables the switch to break ice coatings and resist hang-up when the plunger becomes coated with dirt. The switch is being used as an indicator switch on aircraft. Electrosnap Corp., Chicago 24, Ill.

Circle No. 209 on Inquiry Card

Miniature High Performance Servovalves

A miniaturized high-performance electro-hydraulic servovalve utilizes a simplified design principle proven in the controls of a major operational missile; a tested double-nozzle-flapper hydraulic amplifier and internal mechanical feed-back from the second stage sliding spool to the first stage torque motor. Standard valves are suitable for −65F to 350F operation with maximum flow capacities to 16 gpm at 3000 psi. Special models are available for hydraulic or pneumatic control to 600F. Moog Valve Co., Inc., East Aurora, N.Y.

Circle No. 208 on Inquiry Card

Miniature Feed-Thru Insulator

A new miniature compression mounted feed-thru insulator, with a Teflon body construction has excellent electrical characteristics for high frequency, high temperature and high voltage circuits. The insulator is permanently attached to a chassis by merely compressing it into a mounting hole; wiring time is reduced by virtue of a hole lengthwise through the terminal allowing rapid wire insertion and soldering. The insulator is self-fastening and requires no additional hardware, thus substantially reducing assembly time and costs. Fluorocarbon Products Inc., Rochester 4, New York.

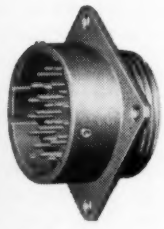
Circle No. 200 on Inquiry Card

BENDIX* PYGMY* MINIATURE ELECTRICAL CONNECTORS

Presenting our big and growing family

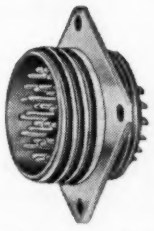
*TRADEMARK

TYPE PT



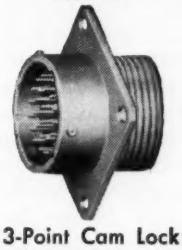
3-Point Cam Lock

TYPE PC



Double Stud Thread

TYPE SP



3-Point Cam Lock Back Panel Mounting

FAMILY FEATURES

- Lightweight, Compact
- Resilient Inserts
- Closed Entry Sockets
- MS Mtg. Dimensions on PC & PT Series
- 5 Key Polarization on PT & SP Series
- Heavily Gold Plated Contacts
- Moisture and Vibration Resistant
- Quick Disconnect—All Series

TERMINATIONS

"A" General Duty

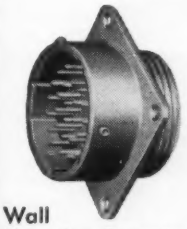
"P" Potting Boot

"A" (SR) Strain Relief

"E" Open Wire Seal

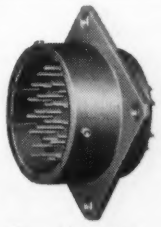
"W" Cable Seal

THE PT SERIES
(Typical of PC and SP)



Wall Mounting Receptacle

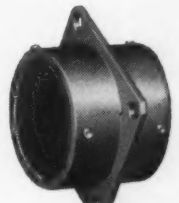
Cable Connecting Plug



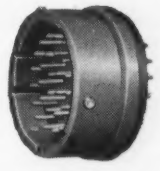
Box Mounting Receptacle

Straight Plug

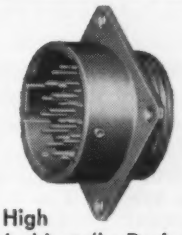
Jam Nut Receptacle



Thru-Bulkhead Receptacle



Solder Mount Receptacle



High Ambient (In Design)

Specify Bendix Pygmy Miniature Electrical Connectors for the minimum space and weight required to serve the most critical circuitry.

Scintilla Division
SIDNEY, NEW YORK

Bendix
AVIATION CORPORATION

Export Sales & Service: Bendix International Division, 205 E. 42nd Street, New York 17, N. Y. Canadian Affiliate: Aviation Electric Ltd., 200 Laurentien Blvd., Montreal 9, Quebec.

CIRCLE 10 ON INQUIRY CARD

Printed Circuit Terminal Block

In usual practice, printed-wiring boards have their printed conductive leads run towards a common edge of the base plate. A connector unit is used to provide a terminal for each printed lead. Such leads are often very close together, so that external wire connections pose a problem. Two-piece connectors sometimes used are expensive and present mechanical drawbacks.

The Kulka type 520 miniature terminal block eliminates soldering. Instead, it provides screw connections integral with terminal pins that slip into standard connector mounting holes in the printed-circuit board. The entire connector unit is securely mounted and connected by dip soldering the pins passing down to the underside of the board. External leads are readily connected or disconnected. Available in 2 to 24 terminals; if more than 24 terminals are required, two or more blocks can be used. Kulka Electric Corp., Mount Vernon, N. Y.

Circle No. 210 on Inquiry Card

High-Speed Digital Processor Handles 10,000 Analog Signals Per Second

A new high-speed digital processor which converts, programs, and records analog signals in digital form on magnetic tape at rates up to 10,000 samples per second is now available.

Known as the MicroSADIC, the basic processor consists of a commutator, digitizer, system programmer, and digital tape unit. Outputs are recorded on digital magnetic tape in pre-selected formats compatible with most computers and peripheral equipment. Digitizing may be in either bipolar binary or bipolar binary-coded decimal form. Completely transistorized and designed for maximum accessibility, the MicroSADIC is mounted in two cabinets, one containing electronics and the other the tape transport. Circuitry is mounted on clip-in printed-wiring boards to facilitate maintenance and permit adaptation of the system to changing requirements. Electronics, assembled in units by function, are packaged in modular "slices" to simplify trouble shooting. Transistors lower cooling requirements and power consumption. Further information appears in CEC Bulletin 1590A. Systems Division, Consolidated Electrodynamics Corp., Pasadena, Calif.

Circle No. 167 on Inquiry Card

New Process Speeds Engineering and Fabrication of Prototype Cams

By using an automatic computer for much of the usual preparatory engineering, Cam Engineering is able to fashion prototype cams more quickly than has been possible previously. To produce a finished cam, the new process needs only the points on the cam surface dictated by the application. Manual computation of the table of ordinates and fabrication of a master cam by traditional tool-room methods are eliminated. Instead, the cam contour is automatically computed to give near optimum dynamic characteristics consistent with passage through the specified points. The data are then fed to a servo-control-led machine tool which cuts the finished cam.

Fabricating the cams on a service basis, Cam Engineering requires only the follower and hub dimensions in addition to the timing diagram coordinates and delivery of the finished cam can usually be made within 48 hours. Because of marked saving in delivery time and in engineering and tool-room costs, the new process is especially useful for making master experimental and prototype cams. The system is suited to making face, cylindrical and disc cams—particularly for high-speed applications. Limited quantity production runs are also feasible. Cam Engineering, Div. of Howard Holmes, Inc., White Plains, N. Y.

Circle 242 on Inquiry Card

Miniature Vibration Pickup

Named the "Vibramite" new miniaturized vibration pickup is an eddy current damped unit with a flat response curve over its full operating range. The unit which weighs 2.75 oz. and is 1.42" sq. and 1" high has the characteristic self-generation with no cathode follower or other impedance matching amplifier required, good temperature stability with high electrical output; tests on the Vibramite indicate that acceleration up to 50g for continuous duty and up to 100g intermittently do not damage the unit. Shock tests were also performed and the pickup operated perfectly even after being subjected to impact shocks up to 100g in all directions, it is reported.

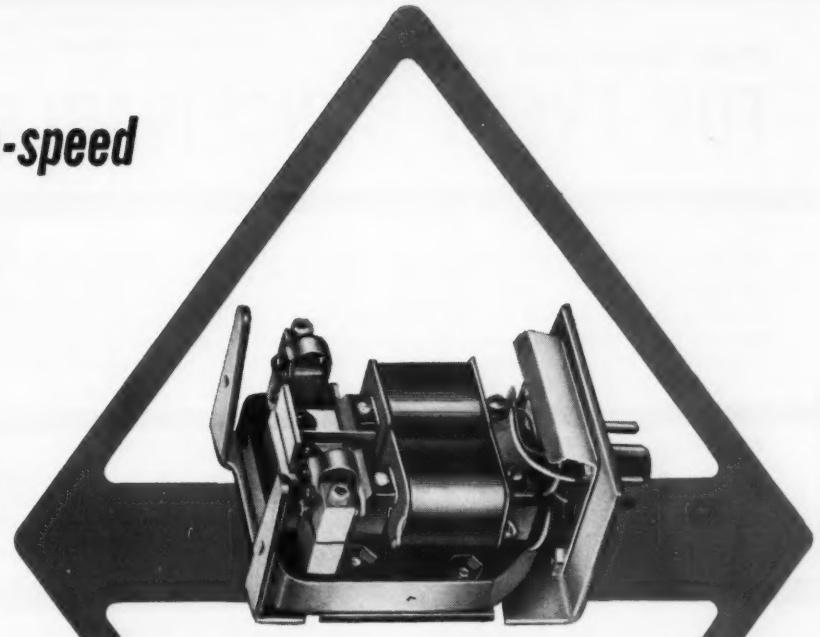
The following are some of the outstanding characteristics of the Vibramite velocity pickup: sensitivity, 96.3 mv/in./sec.—response, flat 40 to 2000 cps ±5% 30 to 2000 cps ±10%—acceleration limit, 50g guaranteed—positioning, omni-directional (no shift in sensitivity; no adjusting). MB Mfg. Co. Div. of Textron, Inc., New Haven, Conn.

Circle No. 224 on Inquiry Card

Small...sensitive...high-speed

POLAR RELAY

for billions of maintenance-free operations



New Type 204 Series PTW Polar Relay has octal plug mounting for universal use. Height, $2\frac{13}{16}$" plus $\frac{41}{64}$" projection of mounting plug; width, $2\frac{9}{32}$" x $1\frac{11}{16}$". Type 202 has standard banana-type terminals; Type 203 has pin-type terminals.

HERE'S A 2-position Polar Relay that can be depended upon for switching a single circuit at high speeds through billions of operations—*without readjustment.*

Substantially smaller than other polar relays, the Automatic Electric Series PTW is designed for telegraph and teleprinter circuits—teletypewriter switching—teletypewriter repeater circuits—plus other industrial and military applications. Type 203 is completely interchangeable with Western Electric 255A relays.

Check these unique advantages

Because of its simple design and compact construction, the PTW costs substantially less than other relays you may have been using. It delivers lightning response (travel time as little as 0.7 of a millisecond!). And its design assures adjustments that stay put practically forever.

Series PTW Polar Relays are available with various type terminals to fit both new and existing applications—including surface mounting of Type 202 in replacement of Western Union Type 17 relay.

For full information, call or write Automatic Electric Sales Corporation, Northlake, Illinois. *In Canada:* Automatic Electric Sales (Canada) Ltd., Toronto. Offices in principal cities.

Automatic Electric Polar Relay is used in selector cabinet of Teleregister Corp. stock-quotation system. Teleregister design engineer, Jim Hartelius, shows how snap-on cover can be removed for visual inspection. He reports " . . . complete reliability . . . almost infinite life . . . virtually never gets out of adjustment."

AUTOMATIC ELECTRIC

Northlake, Illinois • Subsidiary of **GENERAL TELEPHONE**

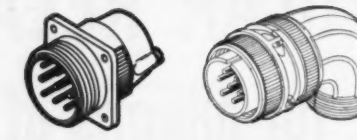
CIRCLE 9 ON INQUIRY CARD

cam-7-line

27,000 CANNON PLUG DESIGNS

FOR EVERY CONCEIVABLE APPLICATION

AIRCRAFT AND ELECTRONIC INSTRUMENTATIONS—MS, MS-A, MS-B, MS-E, MS-R SERIES, conforming to Specification MIL-C-5015D. Vibration-proof—Lightweight—Plugs are available with from 1 to 100 contacts. 15 different insert diameters and 260 contact layouts. 6 shell styles, MS 3100 to MS 3108 with all accessories. Environmental-Resisting MS-E and MS-R Series have interfacial sealing at mating faces and integral grommet seal at wire entry plus—grounding lugs and integral cable clamp.

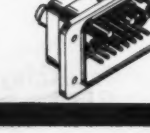


GENERAL CIRCUITRY AND QUICK DISCONNECT—K, RK SERIES, with special acme thread. The all-purpose series with eight insert diameters available. Conduit and cable clamp entry types. 1 to 110 contacts. 10, 15, 30, 40, 60, 80, 115 and 200 amp. silver plated contacts. High quality phenolic, melamine, and formica insulators. Cadmium-plated aluminum alloy shells.

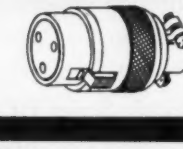
UNIT-PLUG-IN RACK/PANEL-DP, DPB, DPD, DPD2, DPD2R, DPJ, DPS SERIES, available with from 2 to 180 contacts in rectangular inserts. With and without shells; coaxial and high voltage contacts. Permit quick disconnect, interchange, replacement, testing, and inspection of assemblies and sub-assemblies.

AUDIO AND LOW-LEVEL CIRCUITS—P, XLR, XK, O, UA, BRS SERIES, in many shell styles and insert layouts. Straight and 90° angles. Latch-lock types. Wall-mounting, panel, locknut mounting, and adapter receptacles, single and two-gang. 10 and 30 amp. contacts, coaxials.

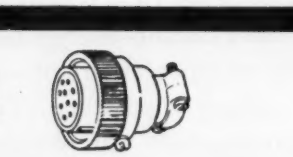
MINIATURE AND SUB-MINIATURE—D, US, DPA, DPX, AND K-MINIATURE SERIES, designed for amplifiers, miniature indicators, computer circuits, telemetering equipment, and general instrumentation of limited space requirements. Variety of shell styles, junction shells, and insert arrangements. Available with from 2 to 50 contacts, plus coaxials.



COAXIAL RF SERIES—available in a wide range of Series and types from sub-miniature to large cable applications. New Cannon adapters available for use with latest cable developments. Cannon's latest RF Plugs include aluminum versions designed for use where weight-saving is a critical design criteria.



GM AND PLUG HARNESS SYSTEMS—Cannon produces a wide range of GM Plugs to fit specific missile applications, ranging from straight umbilical dis-connects to stage-separation dis-connects. Cannon also produces Plug Harness Systems featuring MS or other specified plugs and cables as one unit, available with various contact types and sizes. From 8 to 140 contacts. Highest quality and proven reliability. Varied remote disconnect methods actuated by hydraulic, pneumatic, explosive, or manual means.



The Cannon Electric Company also has available a wide variety of plugs for Battery-Power, Firewall, Watertight, Printed Circuit, and other applications, as well as "Kwik-Term" Terminals and DC Solenoids.
FOR ADDITIONAL INFORMATION on the typical designs illustrated . . . other configurations for your specific applications . . . or the design, engineering and manufacture to your special needs . . . write to Cannon Electric Company—3208 Humboldt Street, Los Angeles 31, California. Please refer to Dept. 0000.

LARGEST FACILITY IN THE WORLD FOR PLUG RESEARCH-DEVELOPMENT-MANUFACTURE

CANNON PLUGS

MARCA REG. IN MEXICO

Factories in Los Angeles, Santa Ana, Salem, Toronto, London, Paris, Melbourne, and Toyko. Distributors and Representatives in the Principal Cities of the World.

CIRCLE 3 ON INQUIRY CARD

COMPONENTS DESIGN

Sequi-Switch For Scanning Transducers

For use in scanning transducers, an electronic switching device, the Sequi-Switch, has many possible applications such as telemetering, dynamic force and pressure studies and multipoint data gathering. It may be used in conjunction with an oscilloscope to give simultaneous readings that can be photographed for analysis. It can be adapted for printed readout. Because of its high signal-to-noise ratio, the Sequi-Switch eliminates the noise problem as well as many other problems encountered in present-day mechanical and electrical commutators.

The Sequi-Switch utilizes a ten-channel beam switching tube that switches at a pre-selected rate up to 1 megacycle. In addition the switching pulses provide, in effect, a carrier for transducers, strain gages, thermistors and capacity pickups. Through appropriate bridge inputs any combination of transducers may be read out. By cascading additional units any number of channels can be provided. Control Devices, Inc., Birmingham, Mich.

Circle No. 251 on Inquiry Card

Matched Thermistors

Matched or interchangeable thermistors of varied sizes and resistance values designed for stable, self-heated applications such as gas chromatography analysis, temperature measuring bridges, temperature control circuits, remote temperature controls, interchangeable calibrated units for thermometry and many others. They also provide an economical means of obtaining close tolerance interchangeability, with matching available to better than 1%. Victory Engrg. Corp., Union, N. J.

Circle No. 245 on Inquiry Card

Small Rectangular Capacitor

If you need a smaller capacitor with much longer life, Plastic Capacitors, Inc., Chicago, Illinois, offers its new type LK rectangular capacitor. Designed for four times the life of MIL-C25A, this new capacitor has case sizes as much as 80 percent smaller than before. Other advantages include superior resistance; better power factor; withstands greater overloads; may be operated to 125C; voltage ratings from 600 to 50,000 volts.

Circle No. 222 on Inquiry Card

Analog Computing Component: Precision Multiplier-Divider

Precision analog computing component with improved long term stability, which is based on a new all-electronic semiconductor network, accepts three variable inputs e_1, e_2, e_3, and provides as output e_1e_2/e_3. Accuracy as a multiplier, including drift, is better than 1/10 v in all four quadrants. Three-digit decade provides an adjustable voltage which may be added to numerator, denominator or output, and serves as an adjustable scale factor for operations involving only two variables. The dynamic response of the unit is determined by a switch setting adjustable. In addition to filament power at 115 vac, the unit requires 100 ma at 300 vdc. Standard range of inputs and outputs is ±50v. Typical applications include analog computation, correlation, precision modulation, and control. No external equipment is necessary for products, ratios, etc. Geo. A. Philbrick Researches, Inc., Boston, Mass.

Circle No. 211 on Inquiry Card

High-Stability Resistors

Two high-stability resistors for missile, aircraft and other applications involving high ambient temperatures maintain their full rating up to 200 and 275C, respectively, and derate to 0 at 325C. They are unaffected by severe ambient conditions such as moisture, dust, salt spray, etc. Resistance of the Type HT-1 (1 watt) is from 200 ohms to 360K ohms with a maximum voltage of 600 volts; resistance of Type HT-2 (2 watt) is 200 ohms to 1 meg with a maximum voltage of 1500 volts. The Victoreen Instrument Company, Components Division, Cleveland, Ohio.

Circle No. 133 on Inquiry Card

Twenty-Five Turn 2-inch Pot

New 25 turn, 2 inch diameter, ultra-precision potentiometer, Model MD 2C-25, has linearity as close of .0075% and very high resolution. Overall length is 2 9/16" with a bushing mount; standard servo mounts also available. The unit meets, or exceeds all critical military specifications for potentiometers, such as temperature, vibration and shock. A ceramic core provides a dimensionally stable, chemically inert and non-hygroscopic foundation. Single-piece, machined aluminum hub furnishes a rugged support and accurate reference. Modified slope control delivers a highly accurate servo-controlled winding in this unique potentiometer. Litton Industries, Inc., Mount Vernon, N. Y.

Circle No. 205 on Inquiry Card

Midget AC Solenoid

AC Midget Solenoid provides maximum power for smaller assemblies with intermittent or continuous duty operation. Plunger stroke is adjustable from 1/16" up to 5/8" with maximum lift of 12 ounces, continuous duty; 19 ounces, intermittent. Coil voltages from 6 to 230 volts, AC; weight: approximately 3 ounces. Guardian Electric Mfg. Co., Chicago, Illinois.

Circle No. 255 on Inquiry Card

Technical Writing Workshop

The Fourth Annual Workshop in Technical Writing will be held on the Tufts University campus for the two-week period July 6 to July 17. Enrollment will be drawn from representatives of industry and government and others actively concerned with problems of technical writing and technical publication.

Lectures, laboratories, and evaluation sessions will be arranged to suit the needs of the workshop members who may have brought with them for discussion non-classified reports, manuals, and other publications which their companies or agencies have prepared. Tuition for the two five-day weeks is $150.

Workshop Director is John H. Mitchell, Communications Consultant and Assistant Professor of Technical Writing, University of Massachusetts. Associate Director is Dr. Paul H. Flint, Acting Dean of the Tufts Graduate School and Past President, Society of Technical Writers.

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Circle No. 203 on Inquiry Card

General Purpose Power Relay

A new general purpose power relay, said to be ruggedly built with single coil construction, employing box-type magnetic field, has movable contact springs mounted on molded phenolic insulating bars to provide positive contact alignment. Contacts of ¼" diameter are available in either silver or silver cadmium oxide, rated singly at 10 to 25 amperes, 110 volts a-c, non-inductive. Comar Electric Co., Chicago, Ill.

Circle No. 174 on Inquiry Card

Major Advance In Small Component Motor Design

A unitized motor, representing a major technological break-through in small component motor design, that is up to 40 percent more efficient than conventional motors of the same type, has been developed by the General Electric Company. Available first in 4-pole, KSM 59-frame, shaded-pole and permanent-split capacitor ratings up through 1/15 h.p., the revolutionary new motor is designed for use in such air moving and small machine applications as ventilators, heaters, dehumidifiers, air conditioners, coolers, recorders, projectors, business machines and in many other types of small motor-driven equipment. General Electric Co., Schenectady, New York.

Circle No. 155 on Inquiry Card

Magnetic Amplifier as Universal Logic Switch

A new magnetic amplifier combines the reliability of all-static construction and the ability to perform every kind of logical switching function. The small unit serves as an AND, OR or NOT gate, or as a bi-stable memory device. Withstands extremes of shock, vibration and temperature, has no moving parts, requires no servicing and has unlimited shelf and use life. The unit has three input control windings, a bias winding and two gate windings. It operates from a 70V center-tapped transformer on a 115V line at 400 cops, has 2-½ ms response, and accepts a minimum input signal of only 3 milliwatts. Nominal output is 28VDC at 10 watts. The component is fully encapsulated and operates over a temperature range of −60C to +100C. Dimensions: 2"x2"x2¼". Weight: 10 ounces. Other logic-type units are available accommodating up to 8 inputs, and capable of 60 watt output and 60cps operation. Pacific Magnetic Corp., Electronic Center, Romoland, Cal.

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Molded Transistor Transformers

A new series of epoxy molded toroidal type transformers for transistor power supplies provides dc output from mobile supplies of either 6, 12, or 28 volts dc, and exceed the requirements for grade 5 class R units as specified in MIL-T-27A. Toroidal construction permits increased efficiency, reduced noise level, reduction in size and weight and increased life expectancy. Units can be stacked on a single mounting bolt through a centrally located hole, and series parallel connections are easily made to the peripherally located terminal pins. This stacking arrangement makes it possible to double or triple power output with only a negligible sacrifice in efficiency. An appropriate splitting of the feedbeck winding permits operation of most of these units either common emitter or common collector. The operating frequency falls in the range between 2500 cycles for the higher power units, to 5000 cycles for the low power ones. The square wave output characteristic of these transformers may be converted to sine wave by use of available networks. Triad Transformer Corp., Div, of Litton Industries, Venice, Cal.

Circle 194 on Inquiry Card

DC/AC Series Reversible Motor

A new, small size, lightweight universal motor is available in several models, ranging from 6 to 48 volts DC or AC input, and is rated at 1/75 h.p. in intermittent duty, or 1/125 h.p. continuous duty. Weight is under 10 ounces. Overall dimensions are approximately 1¾" diameter by 3" long, plus the ¾ to 1" shaft extension. Carter Motor Co., Chicago, Ill.

Circle 156 on Inquiry Card

Missile Quality A.C. Drive Motors

New data sheet tabulates complete line of −55C to +85C missile quality a-c drive motors, voltage, frequency cps, no. phases (supply), no load speed (RPM), capacitor (mfd), running current amperes, running watts input, output, weight, gear ratio and type number. John Oster Manufacturing Co., Avionic Division, Racine, Wisconsin.

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Circle 169 on Inquiry Card

Bristol miniature pressure switch

features ultra-reliable precision pressure element. Exclusive design provides outstanding resistance to shock, vibration, acceleration and overpressures.

These Bristol miniatures, widely proved in modern aircraft, are designed for switching electrical circuits in response to pressure changes in air, fuels, lubricants, hydraulic fluids, other gases and liquids.

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Write for Bulletin AV2010 on Bristol Miniature Gage and Absolute, Adjustable and Differential Switches. The Bristol Company, Aircraft Components Division, 181 Bristol Road, Waterbury 20, Conn. 8.44

SPECIFICATIONS (Fixed pressure setting models)

Normal Working Range – 0 to 100 psi absolute, gage, or differential

Burst Pressure – exceeds 250% of normal working pressure

Electrical Ratings – 5 amp at 125 v, 60 cycle, inductive or resistive
4 amp at 30 vdc resistive
2.5 amp at 30 vdc inductive

Dielectric Strength – 500 v rms between terminals and from terminals to case (MIL-S-8801)

Life at Rated Electrical Load – 40,000 cycles at 125 vac
25,000 cycles at 28 vdc

High Temperature Exposure & Operating – (MIL-S-8801) 250° F

Low Temperature Exposure & Operating – (MIL-S-8801) −65° F

Shock, 30 g, 3 axes – (MIL-S-8801) no change

Vibration – (MIL-S-8801) no contact chatter, no switch damage
300-600 cpm at 0.050" d.a.–set point change–none
operating differential change–none
600-4500 cpm at 0.036" d.a.–set point change–¼ psi
operating differential change–½ psi
4500-30,000 cpm at 10 g–set point change–¼ psi
operating differential change–½ psi

Diameter–1-5/16

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CIRCLE 13 ON INQUIRY CARD

A PRACTICAL RELIABILITY PROGRAM

How to Combine Analysis with Experiments to Determine Equipment Reliability Economically

By Karl Eklund, Staff Engineer, Parameters, Inc.

"Reliability" of an equipment both in common and in engineering usage means the probability that the equipment will perform its functions satisfactorily. In common usage the term is qualitative, but as an engineering term it is quantitative, its meaning is derived from the mathematics of probability.

Since the functions of equipment vary over an almost infinite range, and indeed can vary for the same equipment used in more than one application, determination of reliability is often a difficult task. Determining reliability for a certain component with a given task is generally quite straight forward; but extension of this reliability to other conditions is more difficult.

Problems of reliability testing are similar to those of environmental testing in general. Tests and analytical procedures must be devised such that extrapolation of test performance to performance under actual conditions will be dependable. Let us consider the source of the principles that underlie reliability testing and analysis and attempt to outline a procedure that combines analysis and testing in an optimum way.

RELIABILITY ANALYSIS

Analysis of equipment reliability from known component reliability uses the mathematics of combinatorial probability. The basic relationship is that of simultaneous probability. If the probability of occurrence of the two independent events a and b are respectively P(a) and P(b), then the probability of *both* a and b happening is

$$P(a \cdot b) = P(a) \cdot P(b) \qquad (1)$$

Thus if a system is series connected as shown in Fig. 1, such that a failure of

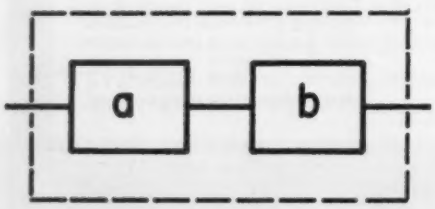


Fig 1—Series Connected System

the system occurs if either a or b fails then the probability of success (i.e. non-failure) is the probability that *both* a and b do not fail, or

$$R^s(a,b) = R(a) \cdot R(b) \qquad (2)$$

The other possible combination is the parallel connection shown in Fig 2, where the sub-systems a and b are connected in such a way that a single failure of a or b does not cause the system to fail. Since the system fails only when both a and b fail, the simplest analysis is to consider U the unreliability of the system. (Note that R plus U = 1 since the item must either fail or not.) In case 2 the unreliability of the system is given by the probability that both a and b fail, so that

$$U^p(a,b) = U(a) \cdot U(b) \qquad (3)$$

or: $R^p(a,b)$

$$= 1 - [1 - R(a)][1 - R(b)] \quad (4)$$
$$= R(a) + R(b) - R(a)R(b) \quad (5)$$

Formulae (1)–(5) can easily be extended to any number of systems in series (case 1) or in parallel (case 2).

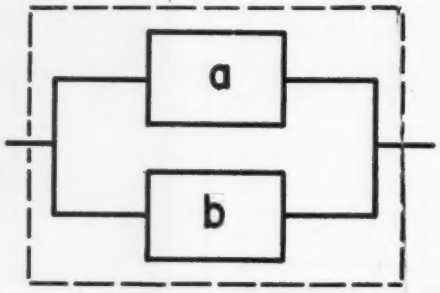


Fig 2—Parallel Connected System

Another method of combining probabilities for events can also be used, but it must be applied carefully. To avoid error, when two independent events have probabilities of occuring P(a) and P(b), the probability that either a or b occur is given by

$$P(a + b) = Pa + Pb \qquad (6)$$

It is easy to slip into the error of using this relation in analysis of the two cases above. The fallacy is that in the first case there are actually 4 events, i.e., both a and b succeed, a succeds and b fails, a fails and b succeeds, and both fail. Failure of the system occurs when any of the last three occur, so that

$$U^s(a,b) = U(a)R(b) + R(a)\,U(b) + U(a)\,U(b) \quad 4\ (7)$$

This is the same result as given in equation (1), which can be rewritten

$$U^s(a,b) = U(a) + U(b) - U(a)U(b) \quad (8)$$

The main reason this error is made is that equation (8) resembles

$$U^s(a,b) \approx U(a) + U(b)$$
$$\text{if} \quad U(a)\,U(b) << U(a) + U(b) \quad (9)$$

but equation (9) can only be used as an estimate of the reliability of assemblies of very reliable components.

Reliability analysis of complicated systems is then just the repeated application of formulae (2) and (4) or (5) as needed.

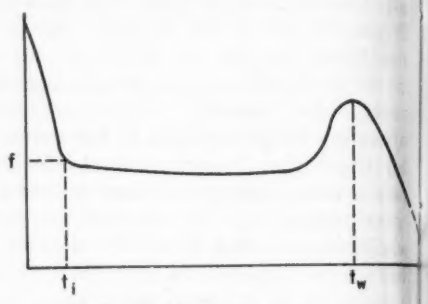


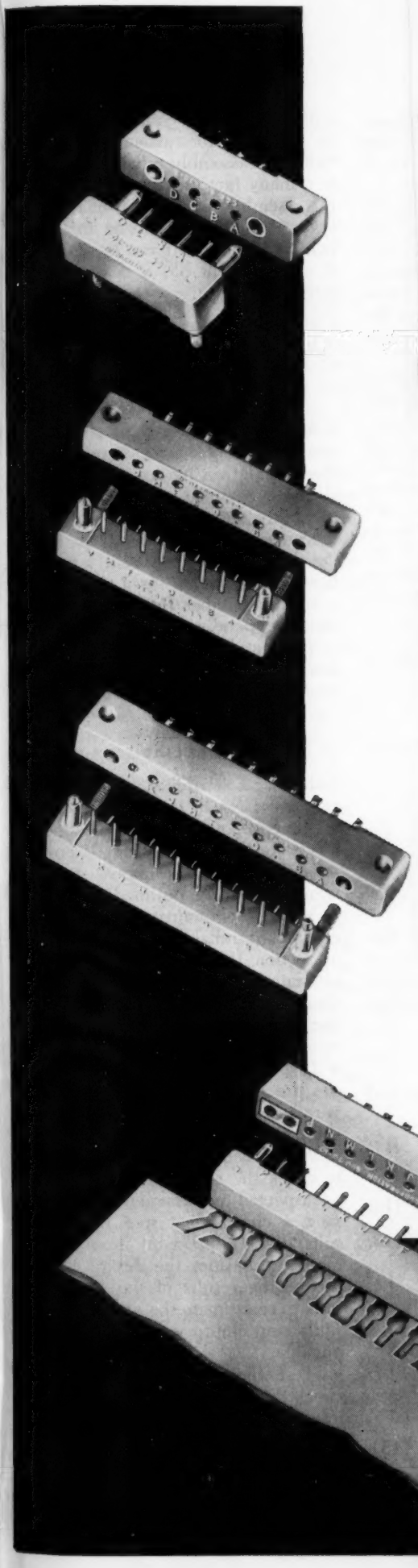
Fig 3—Failure Rate Graph

III RELIABILITY TESTING

Techniques of reliability analysis depend on knowledge gained from reliability testing, since the analysis depends on known component reliabilities. In addition to difficulties inherent in simulating actual operating conditions, (as we have discussed), there are difficulties in evaluating the results of all but the most obvious tests.

The best test, of course, is operation of equipment in the actual environment, but this is usually prohibitively expensive. Next best is testing reasonably large numbers of the equipment under well simulated environments, also very expensive due to the numbers needed. The usual procedure is to test components under the best possible simulated environments and functions and to estimate from this data the reliability of the assembly, and then to test a relatively small number of assemblies to check on the estimates. The first important step is thus the testing of components.

Result of component tests usually can be applied to several items, possibly having different lifetimes, so, it is often economical in the long run to determine the reliability over the maximum lifetime and under the most difficult conditions so as to be able to calculate reliabilities for shorter periods and less difficult conditions. Since extrapolation of reliability under different conditions is rather difficult, check tests may have to be made for the less strenuous circumstances.



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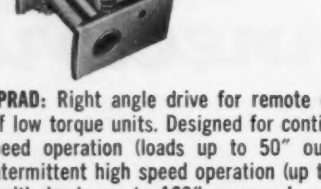
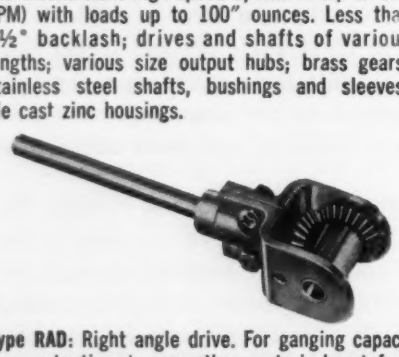
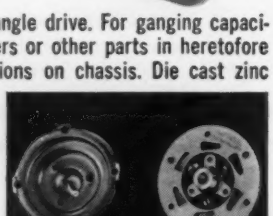


Type PRAD: Right angle drive for remote operation of low torque units. Designed for continuous low-speed operation (loads up to 50″ ounces), and intermittent high speed operation (up to 500 RPM) with loads up to 100″ ounces. Less than 1½° backlash; drives and shafts of various lengths; various size output hubs; brass gears; stainless steel shafts, bushings and sleeves; die cast zinc housings.



Type RAD: Right angle drive. For ganging capacitors, potentiometers or other parts in heretofore inaccessible locations on chassis. Die cast zinc housing gears.



Type AN: Time-tested vernier mechanism. Designed for use with any 3/16″ National knobs and others. Drive ratio: 5 to 1; drive shafts: 3/16″, 1/4″ or to specifications; fully insulated output shaft coupling; output hub fits ¼″ shaft; readily adaptable to many types of drives.

Type AVD: Vernier mechanism. Similar to type AN (above) except that output-shaft is non-insulated. Dimensions: over-all diameter 2-9/16″, length 1-15/32″.

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When the environment is the same, but required lifetimes are shorter than in the test, calculation of reliability is quite simple.

Results of a long test on a typical component might show results like those in Fig 3, which gives the fractional rate of failures plotted against (t). Test results may also be shown as a survival plot, as in Fig. 4, where the number surviving is plotted against (t).

Both of these graphs show three characteristic regions: initial failures, random failures and wear-out failures. Quite often, components are subjected to production inspection that removes most of the marginal units that produce initial failure, and many units are such that they almost never get a chance to wear out (where random failure probability is high over wear-out lifetime) so that in many cases the region of interest is the middle or random region.

Define:

m = number of units at beginning of random failure period
n_f = number of random failures
n_s = number of survivals
f = failure rate during random failure period
R = reliability = n_s/m
U = Unreliability = n_f/m

Then by definition

$$n_s + n_f = m$$

$$R + U = 1$$

Since failure rate is constant in this random failure region, the number of failures per unit time is proportional to the number of survivals and the failure rate

$$-\Delta n_f/\Delta t = n_s f \qquad (10)$$

Taking this expression to the limit and integrating we get

$$n_s/m = \exp(-ft) \qquad (11)$$

Then by substitution

$$R = \exp(-ft) \qquad (12)$$

$$\text{and } U = 1 - \exp(-ft) \qquad (13)$$

When

$$n_f << m \qquad (14)$$

so that $n_f/m = U = 1 - \exp(-ft)$ is very small then

$$1 - \exp(-ft) \approx ft$$

$$U \approx ft \qquad (15)$$

Results of reliability test should be a survival or failure rate plot like figures (4) or (3). Equation (12) can then be used to calculate reliability. A difficulty arises when equation (2) is used to calculate the assembly reliability. Since the assembly reliability may contain many factors, the possible error in the assembly reliability estimate will be several times the errors in the component reliabilities. It can be shown that if a component has a constant failure rate, then

$$U = n_f/m \pm (n_f/m^2)^{1/2} \qquad m >> n_f >> 1 \qquad (16)$$

$$= n_f/m\,[1 \pm (1/n_f)^{1/2}]$$

When n_f is smaller than about 5 the actual probable error is even larger than that given by equation (16). To obtain a reasonably accurate value of reliability, the quantity n_f must be significant. Accurate estimate of reliability then requires testing a large number of components for a short time or a smaller number for a long time, the choice depending on the relative costs of items and test time; but in any case the operating lifetime must be significantly longer than t_i and less than t_w.

IV COMPLETE RELIABILITY PROGRAM

Details of a reliability program depend to a great extent on the characteristics of the equipment being evaluated, but a general procedure for determining reliability of an equipment most economically can be outlined.

- Make a preliminary analysis of the equipment reliability by the methods of section II, using the best available estimate of component reliability. This should be done at the design stage, and the results should be used to eliminate weak portions of the design.
- Test the components whose reliabilities are not known with sufficient accuracy and establish their reliability, using the relations given in section III.
- Where necessary, test subassemblies to check the estimates, and to uncover unsuspected environmental difficulties (e.g. a chassis "hot spot"). If the results differ appreciably from the estimates, reconsider the design carefully.
- Use the results of the subassembly tests to re-estimate the equipment reliability and improve weak spots where possible.
- Test the equipment reliability to check the estimates and to uncover any interconnected design flaws.
- Include in a continuing program of quality control testing tests of component and subassembly reliability, and extrapolate any significant changes in the data to obtain a corrected estimate of equipment reliability.

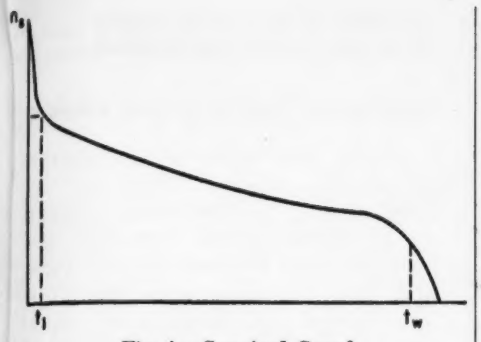

Fig 4—Survival Graph

Expense of the system of analyses and tests given above can be held to a minimum by finding the best combination of full tests and check tests. This combination will depend greatly upon component and test costs, and on the types of components and extensiveness of the tests made.

For most types of equipment, estimation of reliability also depends on what kind of program is specified for maintenance. For example, a maintenance program that calls for wholesale replacement of components before their wear-out may result in a large number of initial failures lowering the reliability of the equipment appreciably. Establishing a maintenance program in support of optimum equipment reliability requires full information about failure characteristics over the entire lifetime of the equipment.

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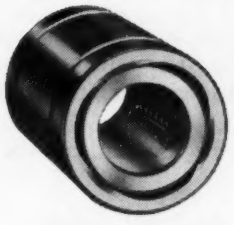

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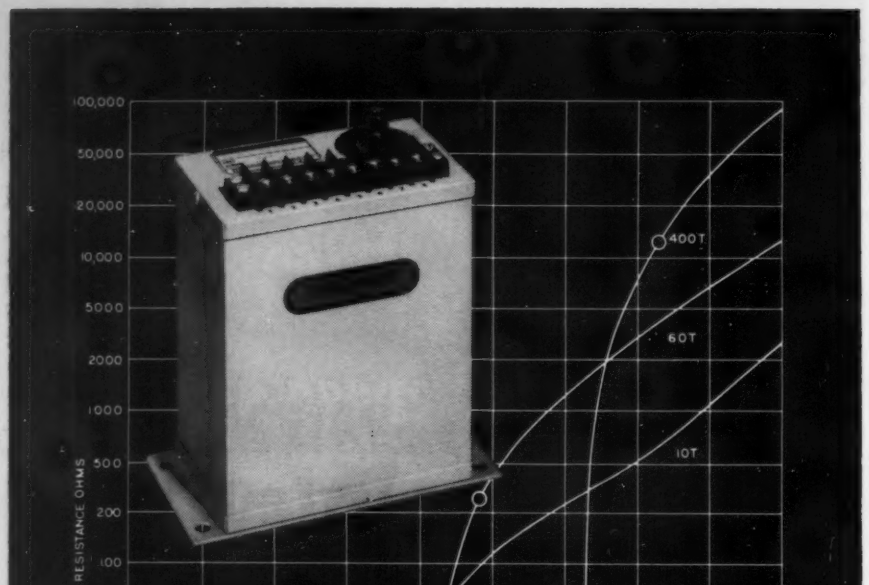

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SYSTEMS DESIGN

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High-Speed Tape Perforator with Simplicity and Long Life

A new, moderately priced, high-speed tape perforator with a punching speed of forty columns per second, has a simplified drive mechanism which requires one eccentric and one cam-generated motion. This reduction in moving parts produces high punching speed and long life. The perforator features four-way staggered positioning of the large rugged punching electro-magnets to provide compactness and maximum force. Rapid response to punching signals is obtained by an overlap. As the drive shaft completes 180 degrees of the complete revolution required to punch each column, the perforator will accept the signal from the next column to be punched. Safety features include an interlock to prevent the feed from advancing tape until a column has been punched. A visual alarm indicates low tape supply, and audible alarms are available. The unit has anti-bounce latches for smoother, more accurate punching, and an odd-even parity check circuit will spot errors in punching. Data Instrument Div., Telecomputing Corp., Los Angeles, Cal.

Circle No. 130 on Inquiry Card

Digital Write/Read Magnetic Tape Amplifiers

A family of write/read amplifiers affords users of digital magnetic tape transports a wide choice of characteristics. Tape speeds from 1 in/sec to 150 in/sec can be accommodated, with a response to minimum signal levels as low as 150 microvolts. Designed for compatibility with existing return to zero and non-return to zero recording systems, this amplifier equipment offers a choice of d-c level or preselected pulse width for output use. D.C. level or pulse is acceptable for input to write amplifier. Other significant features are: gated output for direct strobing, clock playback for data strobing, IBM clock generation, and choice of read-write switching mode. Potter Instrument Co., Inc., Plainview, N.Y.

Circle No. 125 on Inquiry Card

WORTH FILING

Digital Instrumentation Catalog

Twelve-page two-color digital instrumentation catalog describes 32 instruments and accessories including new transistorized 150kc frequency-period meter, new digital voltmeter, and fast versatile digital printer, universal counter-timers, frequency-period meters, frequency meters, time interval meters, inline-inplane readouts, electronic go-no-go gauges, preset counter controllers, and decade counting units.

Source: Computer-Measurements Corp.
No. Hollywood, Cal.
For your copy: Circle No. 129 on Inquiry Card

WORTH FILING

Servo Motors Catalog

Twenty-page catalog lists and fully describes all basic model of complete line of precision made servo motors, sizes 8 to 29, for scientific, military and industrial applications. Included are dimensional drawings, and physical, electrical and mechanical characteristics.

Source: John Oster Manufacturing Co.
Racine, Wisconsin
For your copy: Circle No. 131 on Inquiry Card

New In-Line Servopackages

Systems engineers in need of servo position indicators, integrators and other servosystem assemblies can have quick delivery of in-line servopackages. Compact, space-saving modules free the designer from positioning, testing, matching and aligning individual components. They are available with size 8, 11, 15 and 18 servomotors; servomotor-rate generators; and inertia and velocity damped servomotors. Helipot, Fullerton, Cal.

Circle No. 128 on Inquiry Card

Nuclear Magnetic Resonance Field Control

Nuclear magnetic resonance field control unit, provides a means of precise regulation of electromagnets by producing an error signal, derived from the field under control, suitable for closed loop regulation of the magnet power supply. Range of the unit is 310 to 20,000 gauss with standard probes.

The unit consists of three interconnected parts: (1) probe, (2) oscillator, (3) field control unit. This latter part consists of a power supply, lock-in amplifier and modulator. The oscillator is stable to greater than ten parts in a million. Even greater stability can be obtained by cohering it to an external frequency standard.

Modulation sweep range is zero to 20 gauss. Increased modulation facilitates the location of resonance and a modulation control allows decrease of modulation to optimize field control.

The unit operates at 115 volts, 60 cycles at 2.5 amps and weighs 45 lbs. Added versatility of the field control unit permits it to be used as a high gain null detector for precise control of temperature, pressure, and impedance by the addition of an external bridge. Harvey-Wells Electronic, Inc., West Roxbury, Mass.

Circle No. 204 on Inquiry Card

Environmental-Resistant Harness and Cable Assemblies

New molded harnesses and special electric cable assemblies designed for maximum protection against specific environmental hazards over a broad temperature range, result in increased harness and system reliability. Research in processing polyvinyl chloride, silicone rubbers, epoxies, neoprene rubber and a variety of molding compounds permits the utilization of materials for a variety of applications. Harnesses can be constructed for −120F to +500F continuous use, or to 600F intermittent use. Revere Corp. of America, Wallingford, Conn.

Circle No. 259 on Inquiry Card

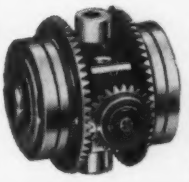
T.V. Cooler

The U-522477 Mechanical Refrigeration System, a fractional tonnage refrigeration system, designed to maintain optimum operating temperatures, applies to a television camera used in conjunction with a radar system. The unit is self-contained and consists of a compressor, condenser, evaporator, air moving devices and controls required to meet the performance characteristics under military environmental conditions. United Aircraft Products, Inc., Dayton, O.

Circle No. 127 on Inquiry Card

computing components from Librascope

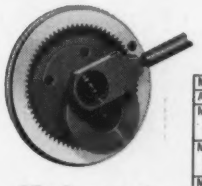
New precision differentials with double-bearing pinions



Model	36	37
Pinions	2	2
Bearings per pinion	2	2
Shaft Type	hollow	solid
Shaft Size	1/16" ID	1/4" OD
Inertia	0.075 oz-in²	0.075 oz-in²
Max. breakaway torque	0.25 oz-in	0.25 oz-in
Max. backlash (minutes of arc)	7'	7'
Max. static load	6 in-oz	6 in-oz
Max. gear input speed	1200 rpm	1200 rpm
Working Circle	1.090"	1.090"
Length	0.980"	0.980"
Weight	1 oz.	1.5 oz.

LIBRASCOPE's new Model 36/37 differential with two miniature precision bearings per pinion provides greater accuracy and less backlash than previously available models. Can be ordered with either a hollow or solid shaft. The hollow shaft version (Model 36) employs a unique method of internal shaft clamping which prevents marring of the shaft and reduces overall length. A new and superior method of attaching side gears is also provided.
SEND FOR DATA SHEET 36-37

Angular to lineal conversion with sine-cosine mechanism



Model	43	44
Accuracy	0.2%	0.15%
Max. breakaway torque	0.1 oz-in	0.1 oz-in
Max. recommended speed	100 rpm	100 rpm
Max. recommended load on pin	4 oz.	4 oz.
Throw	3/4"	1"
Diameter	2"	2 1/2"
Weight	2.0 oz.	2.5 oz.

The LIBRASCOPE Sine-Cosine Mechanism accurately converts angular rotating motion into lineal sine-cosine movement. Instantaneously solves problems of changing variables involving vector components, range and bearing computation, flight computation, and many other trigonometric functions.
SEND FOR DATA SHEET 43-44

LIBRASCOPE, INC.
Commercial Division
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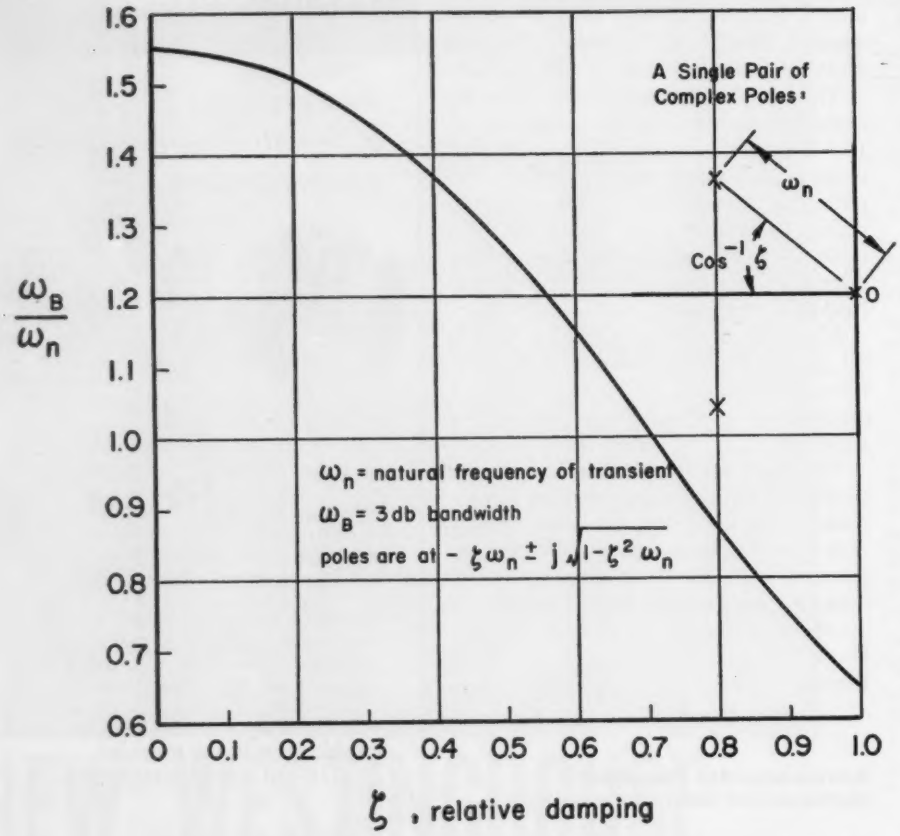
CIRCLE 18 ON INQUIRY CARD

M. J. Hellstrom
Westinghouse Electric Corp
Supervisory Engineer

BANDWIDTH FOR A PAIR OF COMPLEX POLES

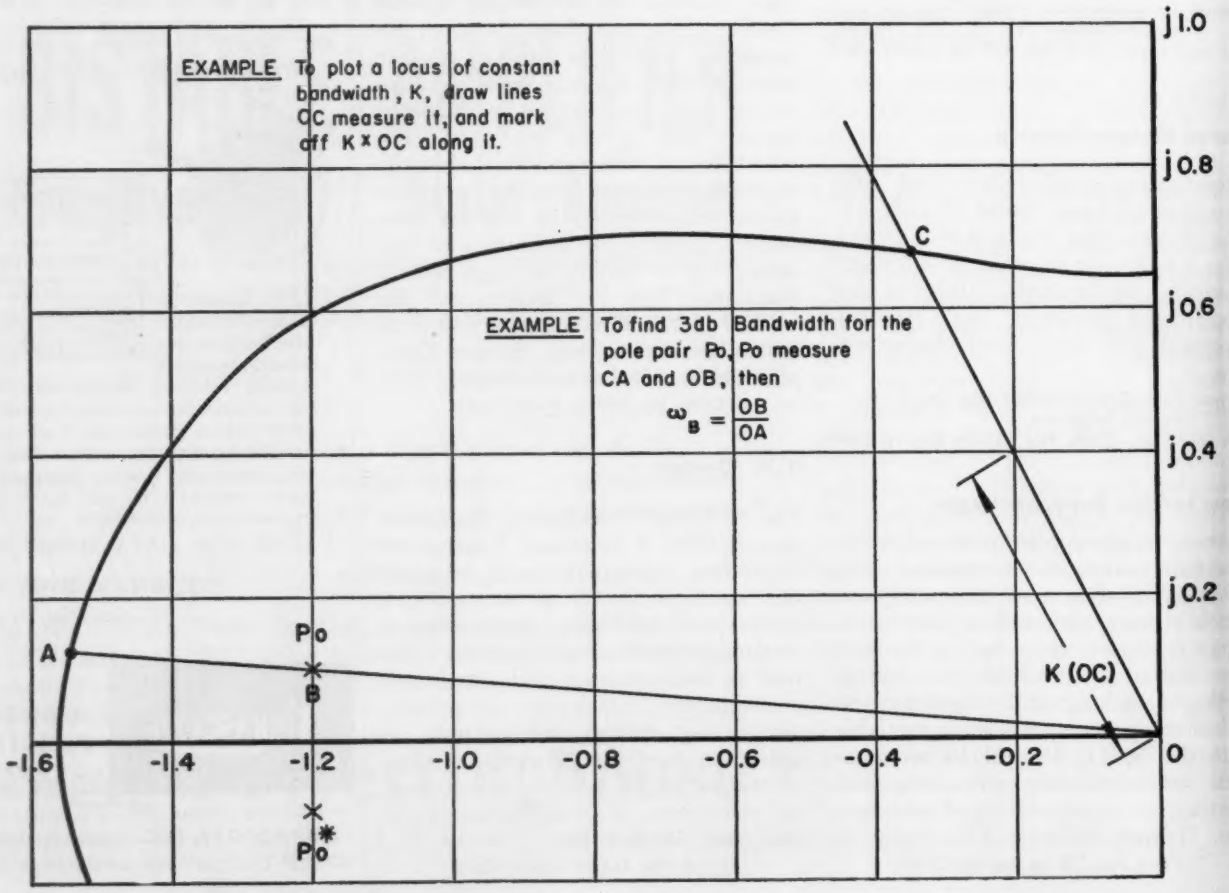


Feedback control systems often are characterized by a single dominant pair of complex poles, $\omega_M[-\zeta \pm j(1-\zeta^2)^{1/2}]$. The half power bandwidth, ω_B, for such a system is related to the natural frequency, ω_M, associated with the poles and with their relative damping, ζ, by the formula

$$\omega_B = \omega_M[1 - Z\zeta^2 + (2 - 4\zeta^2 + 4\zeta^4)^{1/2}]^{1/2}$$

A plot of this, which appears in Figure 1, is useful in rapidly determining the 3 db bandwidth from the position of the poles.

The same information may be presented in another convenient form, i.e., a contour of constant bandwidth in the complex frequency plane. Figure 2 shows the contour for unity bandwidth. It shows the locus of a pair of conjugate complex poles such that the system always has unity bandwidth. It can be scaled to any desired bandwidth, of course. In synthesis work, particularly in conjunction with the Root Locus Method, such constant bandwidth contours tell how bandwidth will vary as poles move in the complex frequency plane.



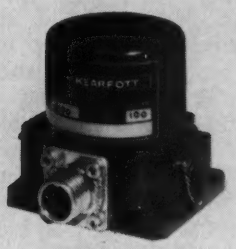
BASIC BUILDING BLOCKS

SERVO SYSTEM COMPONENTS

- Servo Motors—Frame Sizes 5-25
- Synchros and Resolvers—Frame Sizes 5-25
- Tachometers—Damping, Rate, Integrating
- Transistorized Amplifiers—High Temperature 2.5-16 watts

Synchros—Size 25—20 sec. max. error

HYDRAULICS



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Systems

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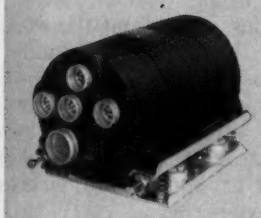

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- Guidance
- Analog and Digital for Missile Applications

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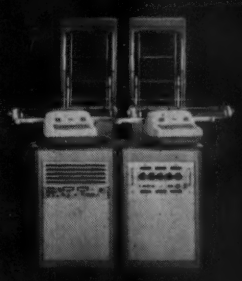

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CIRCLE 19 ON INQUIRY CARD

NEW TECHNIQUES

MILLIMICROSECOND PHOTOGRAPHY

Electrostatic Image Control, Focussing and Deflection

In recent years ultra-high-speed photography has found increasing use in studies of extremely rapid phenomena such as growth and decay of electrical discharges, detonation propagation and shock wave formation. Since these phenomena have time histories that last only a few microseconds at most, the cameras must be capable of taking pictures at frame rates of the order 10^6 per second with exposure time during each frame of 10^{-6} seconds or less.

Mechanical cameras using high speed rotating mirrors and stationary films have been used extensively for ultra-high-speed photography. Cameras of this type offer good image resolution and a relatively large number of frames. However, difficulties arise in synchronizing these cameras with the event to be photographed. Also, many phenomena of interest cannot be photographed with these cameras because light intensities are too low.

Cameras using Kerr cells and Faraday cells as electronic shutters have also been successfully used in ultra-high-speed photography. These cameras are more easily synchronized with events than mechanical cameras, but in general require more light from the event than mechanical cameras because of light losses in the cells.

Since World War II, there has been considerable activity in the development of image converter tubes as electronic shutters using magnetic deflection of the electron images to obtain multiframe pictures. Image converter cameras are easily synchronized with the events. Under certain conditions, these cameras require less light from the event than previously mentioned cameras because of the ability to obtain light amplification within the image converter tube.

Precision Technology, Inc. of Livermore, California has designed a camera that uses a new type image converter tube designed for image control, focussing, and deflection by pure electrostatic means as opposed to electrostatic-magnetic means in previous types.

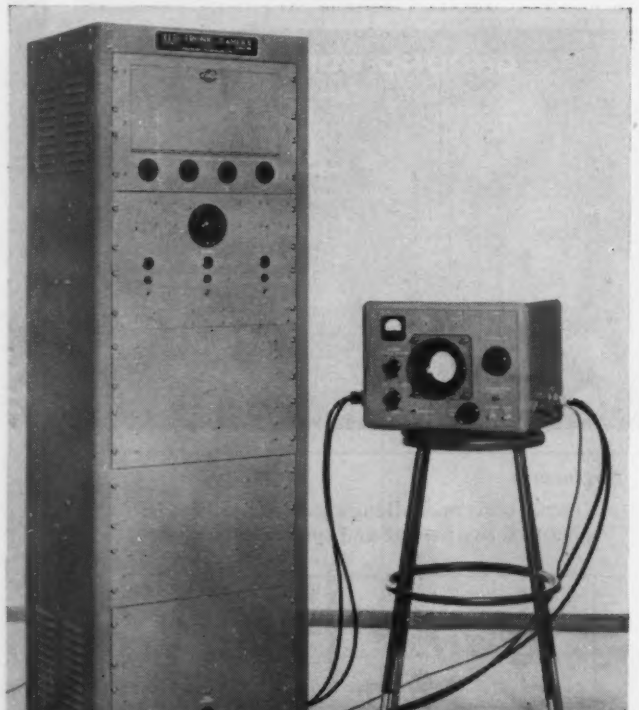


Fig 1—The PTI Image Converter Camera was designed for exposure time of 0.05 to 1.0 microsecond, a frame spacing of 0.5 to 50 microseconds with 1 to 5 frames as selected. Control rack contains from top to bottom a time sequence generator, primary power control panel, low voltage power supply, frame pulse generator, and the high voltage supply.

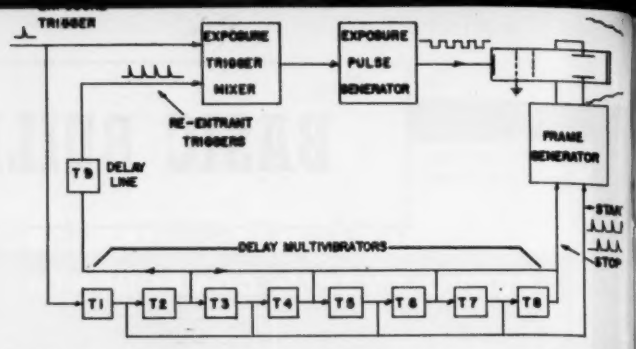


Fig 2—Block diagram shows circuits used to control operation of the image converter tube. An event trigger initiates the first exposure pulse and at the same time triggers a chain of monostable multivibrators. Outputs of the odd numbered vibrators initiate position deflection of the image across the screen. Even numbered multivibrators stop the deflection process and initiate the exposure at each position. A small time delay in the shutter branch of this circuit permits the deflection voltage to reach a rigidly constant value thereby avoiding motion of the image when the shutter is "open".

GRID SHUTTER

Electrical pulses can be generated in a variety of ways having the rise times and duration times required for image converter photography. Hydrogen thyratrons and/or mechanical switches used as transmission line discharge devices produce suitable pulses for image converter work; in fact, they can be made to surpass vacuum tubes where rise times and transition times on a single pulse basis are the only considerations. However, vacuum tubes and their associated circuits offer greater flexibility where synchronization repetition rate, and precise programming are added considerations. Therefore, designers selected hard vacuum tubes exclusively in the camera circuits.

Shutter pulser (Fig 3) consists basically of a monostable multivibrator followed by an amplifier stage. Pulse duration time is controlled by varying the R of an interstage RC network. An input cathode follower permits reflection-free termination of the incoming transmission line and provides unilateral transmission into the multivibrator proper. An intermediate cathode follower delivers a high impedance take-off from the multivibrator and provides power to drive the output amplifier stage. Output amplifier stage is biased to cut-off and is driven into grid conduction by the signal. This overdriven mode of operation aids the production of flat topped exposure pulses and at the same time minimizes the rise time contribution of the stage. The shutter pulser drives the cathode rather than the grid of the image converter tube since this obviates the need for reversing the pulse polarity. At the operating speeds desired, the heater to cathode capacitance of the intermediate cathode follower seriously increases decay time, unless a corrective procedure is introduced. As a corrective means, a decay control tube normally biased to cut-off is added as part of the cathode load. This tube is pulsed into heavy conduction at the end of the useful output pulse with a signal obtained by differentiating the out-of-phase interstage signal.

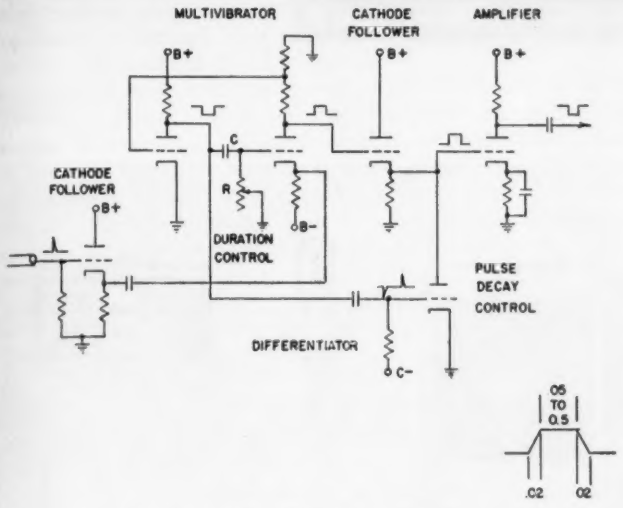


Fig 3—Shutter Pulse Generator.

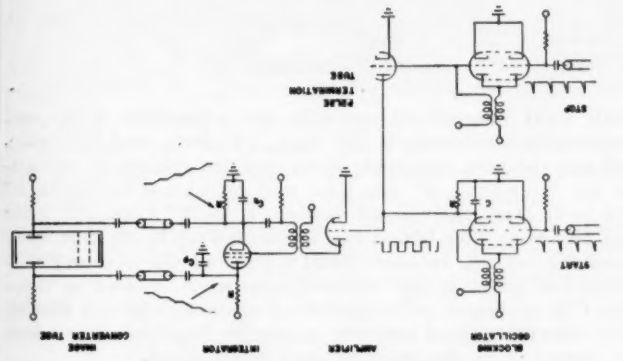


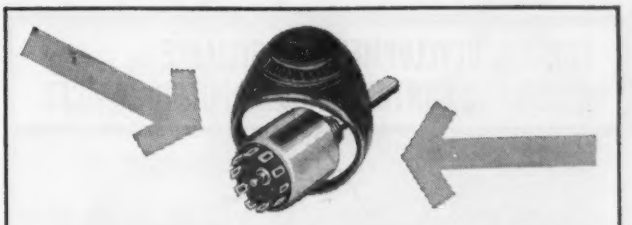
Fig 4—Frame Pulse Generator.

FRAME PULSE GENERATOR

Fig. 4 is a simplified schematic of the framing circuit. A frame start signal from the timing circuits triggers a modified blocking oscillator which charges a capacitor in the second cathode circuit. After the charging action the tube returns to a nonconducting state and C discharges slowly through a large resistor R. A frame stop signal triggers a second blocking oscillator which momentarily drives a pulse termination tube into heavy conduction, discharging C. The voltage wave on C has a duration essentially equal to the difference in arrival time between the start frame and stop frame signals. RC is made large compared with the longest pulse length desirable, so that the voltage pulse on C is essentially square topped.

The voltage pulse so generated is amplified and impressed between grid and cathode of an integrating output by a bootstrap connection. The integrating stage is normally cut off. When pulsed into condition, charge is transferred from a plate capacitor C_p to a cathode capacitor C_k. When the total plate capacitance is made equal to the total cathode capacitance the voltage rise on the cathode is exactly equal to the voltage fall on the plate. When pulsed in rapid succession two staircase functions of equal amplitude but opposite polarity are generated. These are transmitted to the image converter tube on individual unterminated transmission lines, which in themselves form part of the capacitive loading on the tube. The plate feed resistor, cathode resistor, and other necessary resistors are made large so that the recovery time of the plate and cathode are long by comparison with the exposure time.

Circle No. 104 on Inquiry Card



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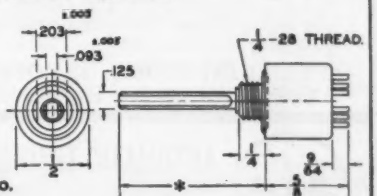

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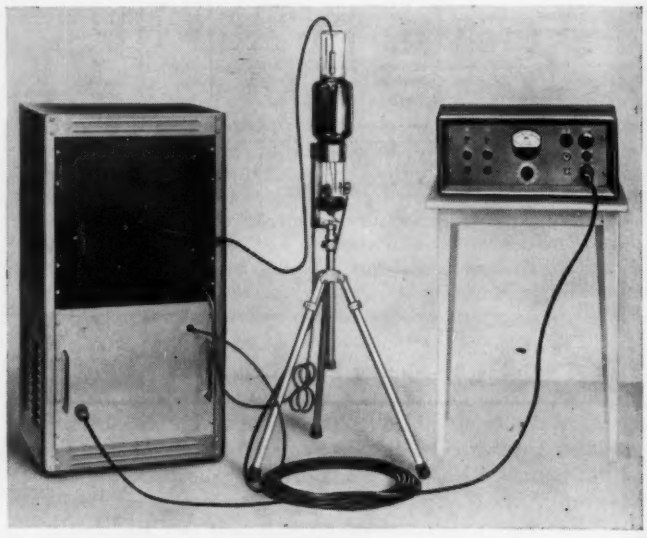
NEW TECHNIQUES



Flash x-ray control cabinet with the adjustable delay and power circuit controls, is 10" high, 15" deep, and 22" wide, and may be rack-mounted. X-ray console cabinet is on casters for "move about" use, and may be placed as far as 50 feet away from the control cabinet. It is 40" high, 22" wide and 18" deep. The tripod can be located up to six feet away from the console cabinet. Total weight of the equipment is about 250 pounds. The entire system may be fired in three ways: by an input pulse generated remotely; by the closing of a remotely placed contact; manually, by depressing a button mounted on the front of the control panel.

FLASH X-RAY EQUIPMENT

Freezing High-Speed Explosions

Zenith Radio Research Corporation has developed a new flash x-ray equipment for use in recording explosion processes and measuring the speed of hyper-velocity objects. Utilizing a newly developed Zenith air-core pulse transformer and special "triggering" circuits, the equipment performs with a degree of reliability and accuracy which company officials say has never before been achieved by flash x-ray systems. In addition to virtually eliminating "too early" as well as "too late" firing of the flash x-ray tube, the use of pulsed accelerating voltage and precision triggering allows a uniform high level output of radiation.

Flash of x-radiation is so brief (about one-sixth of a millionth of a second) and the time of its occurrence under such precise control that the motion of a high speed projectile in flight may be completely stopped at precisely the desired position—for example, just when the projectile leaves the muzzle of the gun, or when its nose pierces a piece of armor plate.

Dr. L. Curtis Foster, Zenith's Director of Research said that the equipment is capable of producing x-ray type "shadow pictures" of high speed phenomena such as the "burning" pattern of solid fuel propellants used in rocketry and missile work. Using two or more of the x-ray units, Foster said, measurements can be made of the speed of hyper-velocity objects.

Unlike other flash x-ray equipment in which condensers apply the full accelerating voltage directly to the flash x-ray tube, Zenith's equipment stores the energy at a rela-

tively low potential. The pulse transformer steps it up to the required peak accelerating voltage only when the tube's operation is desired. Full accelerating voltage is obtainable within the range of 60-120 kilovolts.

In addition to assuring the reliability of the x-ray tube's operation, Foster stated, the use of a pulse transformer reduces the amount of reverse current through the tube. There is less sputtering of tungsten and consequent degradation of the tube, he said, which prolongs its useful life. Operating at 100-120 kilovolts "boosts" the number of "flashes" obtainable from each tube from about thirty to more than one hundred.

Duration of the x-ray pulse, about one-sixth of a microsecond, produces a film blackening sufficient for shadowgraphic work at distances up to 12 feet, and also up to 16 feet—depending upon which type of flash x-ray tube is used. Intensities are adequate for fragmentation or explosion studies at distances up to 6 feet after penetration of the x-rays through 1" of plywood.

Circle No. 108 on Inquiry Card

Retaining Ring Tools
Speed Assembly Operations

Two new retaining ring assembly tools which combine applicators and magazine-fed ring dispensers in one unit have been developed by Waldes Kohinoor, Inc., Long Island City, N.Y. Known as the Truarc "Ring-Gun" and the "Ring-Jector," the tools are designed for the electronics and electrical appliance and equipment industries.

Ring-Gun and Ring-Jector may be used with Truarc series 5103 crescent rings, series 5133 E-rings and series 5144 reinforced E-rings for shafts ranging in diameter from 0.125" to 0.375". Rapid loading with the firm's new Rol-Pak stacked rings assures a constant supply of the fasteners.

To install a ring, the trigger is squeezed so that the first ring in the stack protrudes partially from the applicator blade. The ring is then inserted into the groove and the entire tool pushed forward to lock the ring on the shaft.

The Ring-Jector, which is less expensive than the Ring-Gun, is recommended for assemblies where clearance dimensions prohibit placing a tool over the work piece in an axial direction, or where smaller rings are used which do not require substantial force for spreading to clear the shaft.

According to J.C. Darby of Waldes Kohinoor, the Ring-Gun and Ring-Jector offer a number of advantages:

Compactness—The tools combine an applicator and dispenser in one portable unit. On a mass-production assembly line it is a simple matter to suspend either tool from the ceiling or a table bracket so that the operator need not spend time and effort picking up the tool and putting it down.

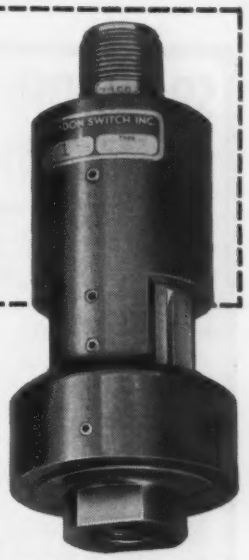
Faster Ring Assembly—To install a ring on a shaft or stud with Ring-Gun, the operator merely places the tool over the work piece, inserts the tongue of the actuating lever into the groove and squeezes the trigger. With the Ring-Jector, the operator compresses the trigger, inserts the partially protruding ring into the groove and then pushes the entire tool forward.

Easier Handling of Spring-Loaded Parts—In assemblies in which the retaining ring is used to lock components under spring pressure, the jaws of the Ring-Gun—or the tip of the applicator blade of the Ring-Jector may be used to depress the parts to provide access to the groove.

Mobility—The tools make possible ring applications on work pieces which cannot be brought to fixed assembly stations.

Circle No. 122 on Inquiry Card

Introducing
a new line of
PRESSURE SWITCH/ TRANSDUCERS!



- *For Aircraft, Missile & Rocket Applications*
- *8 Pressure Ranges, covering 0.5 to 4,000 psi*
- *Available with Optional Vibration Isolator*
- *Qualified to MIL-E-5272A Specifications*
- *External Pressure Setting Adjustment*

The new Haydon 1500 Series Pressure Switch/Transducer weighs only 6 ounces—yet operates accurately at up to 4,000 psi! Interchangeability of internal modular components permits use of the same small, rugged housing over the complete pressure span from 0.5 to 4,000 psi.

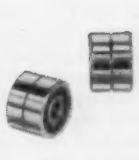
This environmentally-sealed unit is designed for use in all types of pressure systems . . . fuel, hydraulic, oil, pneumatic, chemical and gas. The entire assembly is resistant to corrosive operating media, including water-alcohol solutions, nitric acid and hydrogen peroxide, among others.

HAYDON Switch INCORPORATED
WATERBURY 20, CONNECTICUT

CIRCLE 23 ON INQUIRY CARD

A Match for any Gyro's Torque!

Each matched pair of MPB spin bearings is precisely duplexed to keep motor speed constant and torque low even under severe thrust loads. Noiseless operation . . . life-long lubrication. Interested? Details from MPB, Inc., 1305 Precision Park, Keene, N. H.



MPB helps you perform miracles in miniaturization

MPB
MINIATURE PRECISION BEARINGS INC.

CIRCLE 24 ON INQUIRY CARD

SPACE OR WEIGHT LIMITATIONS?

B52 | C41 | C47

Specify Local Mounted UE SKELETON TYPE TEMPERATURE CONTROLS

UNITED ELECTRIC temperature controls are precision-built, compact and economical. Type B-52 was designed especially for controlling air temperatures . . . Type C41 and C47 for liquid or hot plate temperatures . . . These controls are direct-immersion units designed for easy installation.

Temperature Ranges	Type C41 & C47 100° or 200° between 0° and 425° F limits. Type B52 calibrated 40° F spans between 30° and 120° F.
Thermal Assemblies	various immersion lengths . . . liquid-filled seamless brass bellows operate by hydraulic action
Switch Ratings	15 amps or 20 amps at 115 or 230 volts A.C.; also D.C. switches available upon specification
Switch Actions	N.O., N.C., or Double Throw, no neutral position
Electrical Connection	attached directly to screw or solder terminals on switch
Size & Weight	approx. weight . . . 4½ oz., approx. size . . . 3⅞" x 2" x 1¼"
Variations	design variations available upon specification

UNITED ELECTRIC *manufactures a complete line of temperature, pressure and vacuum controls. For applications requiring custom-built units or modified standard units, call upon a UE application engineer for recommendations. Write for complete specification and pricing data on the Type B52, Type C41 or Type C47 local mounted temperature control, and for information regarding other United Electric temperature controls.*

UE® United Electric Controls COMPANY

85 SCHOOL STREET, WATERTOWN, MASS

CIRCLE 25 ON INQUIRY CARD

MATERIALS

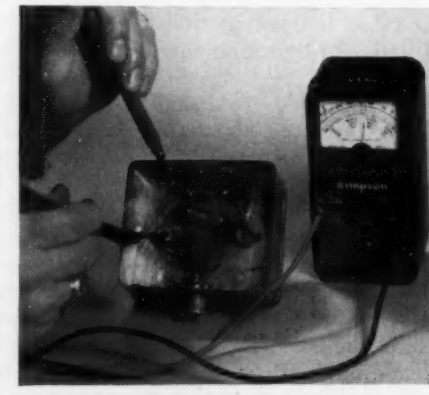
TRANSPARENT POTTING COMPOUND

New Material Permits Check of Potted Parts

New development of a silicone potting material permits visual and instrument checking of individual parts within a potted assembly. Easily applied as a water white liquid with the viscosity of molasses, the material readily surrounds components. Designated as Dow Corning Dielectric Gel, it cures in place to form a resilient mass that combines outstanding dielectric properties with thermal stability and moisture resistance.

No damaging stresses are exerted on delicate parts by this material either during or after cure. Curing time can be varied by approximately 30 minutes to nearly 48 hours. Curing temperatures range from 40 to 150C. Resiliency of the material protects potted parts from shock and vibration, and develops no stresses throughout its wide operational temperature span. Delicate parts potted in Dielectric Gel are not damaged by fluctuating temperatures—a problem with rigid potting materials.

In addition to filling and potting applications, the ma-



Since Dielectric Gel is transparent, potted circuits can be traced visually—test probes accurately directed to connections by simply inserting them through the gel. Having an excellent memory, the Gel "heals" itself upon removal of the test probes.

terial holds promise as a damping material and can also be used as an impregnant for capacitors, magnetic amplifiers and similar devices. Like all Dow Corning silicones, Dielectric Gel retains its physical and electrical properties over a wide temperature span.

Circle No. 119 on Inquiry Card

THERMOELECTRICITY

Converts Heat into Electricity at High Temperatures

An important forward step in the development of thermoelectric materials for the direct conversion of heat into electricity at high temperatures has been made by scientists at Westinghouse Electric Corp. Research Laboratories in Pittsburgh, Pa. They have developed a thermoelectric material—the most efficient of its type yet discovered—for use in the temperature range from 850 to 1500F. This top temperature is well above the melting point of aluminum, magnesium and many common thermoelectric materials.

The new semiconductor material—designed solely for thermoelectric purposes—is a three-element compound known as indium arsenide phosphide, prepared by chemically combining the high-purity indium with equally pure arsenic and phosphorus. Development of the new materials fills a gap in the substances which up to now have been available for thermoelectric power generation. It may find immediate use in thermoelectric devices operating at temperatures well above those previously considered practical.

Circle No. 121 on Inquiry Card

Fibrous Silicone Rubber

Cohrlastic FSR is a unique form of silicone rubber, fibrous in nature, somewhat resembling sponge and foam in properties. Its fibers are oriented in a completely random manner, resulting in a product which has tensile and tear strength superior to silicone sponge and foam. In addition to its improved mechanical strength, its inherent permeability suggests applications which cannot be met by sponge or foam. Samples and data are available. Conn. Hard Rubber, New Haven 9, Conn.

Circle No. 135 on Inquiry Card

WORTH FILING

Iron-Nickel Alloys for Electromechanical Applications

A new publication entitled, "Directory of U.S. Producers of the Iron-Nickel Alloys," is now available to aid those who have the responsibility of obtaining information on, or procurement of, iron-nickel alloys whose end-use depends on special thermal expansivity, thermo-elastic or special magnetic properties; lists composition, manufacturers and forms available to industry.

Source: The International Nickel Co., Inc.
New York 5, New York
For your copy: Circle No. 136 on Inquiry Card

Reactor Metals

Forms and sizes of reactor metals—boron-stainless steel alloys, hafnium, niobium, tantalum, vanadium, zirconium, and zircaloy—are described in new 8-page data bulletin. Bulletin contains maximum and minimum specifications.

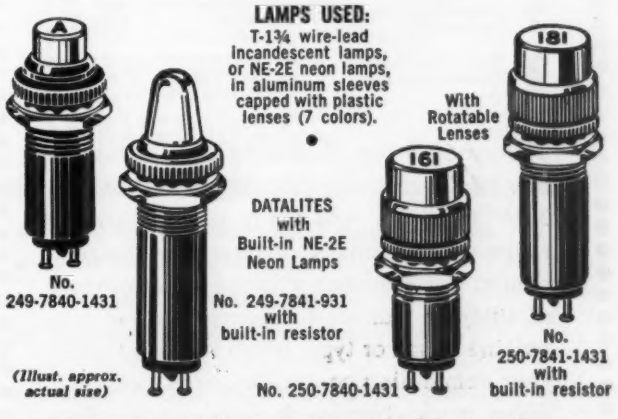
Source: Metals & Controls
Attleboro, Mass.
For your copy: Circle No. 134 on Inquiry Card

In this brochure—complete facts on DIALCO's

DATALITES®

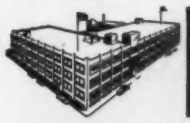
For the Computer-Automation Industries

DATALITES by DIALCO are ultra-miniature Indicator Lights specially designed to meet the critical requirements of the computer-automation fields. Made in 2 basic styles: *Lamp Holders with* DIALCO'S own *replaceable Lamp Cartridges* (see above); or integrated DATALITES *with Built-in Neon Lamps* which are *not replaceable* (see below). Ultra-compact, single units mount in ⅜" clearance hole; the twin-lamp assembly mounts in ¾" clearance hole.


LAMPS USED:
T-1¾ wire-lead incandescent lamps, or NE-2E neon lamps, in aluminum sleeves capped with plastic lenses (7 colors).
With Rotatable Lenses
DATALITES with Built-in NE-2E Neon Lamps
No. 249-7840-1431
No. 249-7841-931 with built-in resistor
No. 250-7840-1431
No. 250-7841-1431 with built-in resistor
(Illust. approx. actual size)

DATALITES have fully insulated terminals and conform to all applicable military specifications. Integrated units are available *with or without built-in resistors.* The cylindrical lenses can be hot-stamped with digits, letters, etc. Complete details in *Brochure L-160.* Send for it now.

SAMPLES ON REQUEST—AT ONCE—NO CHARGE



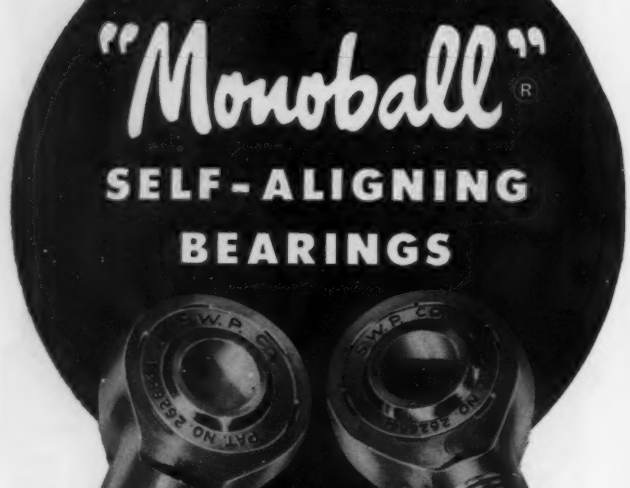
Foremost Manufacturer of Pilot Lights

DIALIGHT CORPORATION

40 STEWART AVE., BROOKLYN 37, N.Y. • HYacinth 7-7600

CIRCLE 26 ON INQUIRY CARD

SOUTHWEST
"Monoball"®
SELF-ALIGNING
BEARINGS



ROD END
TYPES

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PLAIN TYPES

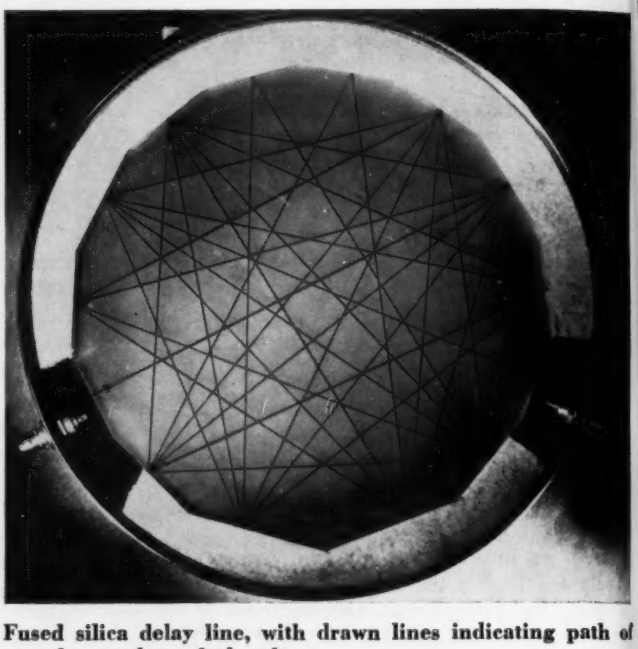
CHARACTERISTICS

	ANALYSIS	RECOMMENDED USE
1	Stainless Steel Ball and Race	For types operating under high temperature (800-1200 degrees F.).
2	Chrome Alloy Steel Ball and Race	For types operating under high radial ultimate loads (3000-893,000 lbs.).
3	Bronze Race and Chrome Steel Ball	For types operating under normal loads with minimum friction requirements.

Thousands in use. Backed by years of service life. Wide variety of Plain Types in bore sizes 3/16" to 6" Dia. Rod end types in similar size range with externally or internally threaded shanks. Our Engineers welcome an opportunity of studying individual requirements and prescribing a type or types which will serve under your demanding conditions. Southwest can design special types to fit individual specifications. As a result of thorough study of different operating conditions, various steel alloys have been used to meet specific needs. Write for Engineering Manual No. 551. Address Dept. EMD-59

SOUTHWEST PRODUCTS CO.
1705 SO. MOUNTAIN AVE., MONROVIA, CALIFORNIA

CIRCLE 27 ON INQUIRY CARD



Fused silica delay line, with drawn lines indicating path of sound wave through the glass.

ULTRASONIC DELAY LINE

Fused Silica Extends Range of Delay Times

Ultrasonic delay lines with very short and extremely long delay times can now store a signal with minimum attenuation for periods ranging from less than 50 to more than 15,000 microseconds. Developed through glass composition research at Corning Glass Works, Corning, N.Y., the new glasses have nearly a zero temperature coefficient of time delay, and can provide delay times up to several hundred microseconds without the need for bulky and heavy heating equipment.

The new glasses are manufactured by the same techniques used in production of optical glass and therefore can be formed into standard glass shapes. The very long delay lines were developed through improvements in fused silica production methods, which make it possible to form plates of pure fused silica up to 48 inches in diameter. The extremely low acoustic attenuation of fused silica makes possible delay time of 15,000 microseconds in a single plane delay line. The company formerly achieved maximum delays of 5,250 microseconds by using folded, or multiple, delay lines.

Circle No. 106 on Inquiry Card

Plasma Plating Method

An 8-page booklet describes new plasma arc service for plating metals at temperatures up to 30,000 degrees Kelvin. The new torch service has already been extensively used in connection with the manufacture of parts for missiles, rockets, electronic and nuclear components, and other parts used in civilian as well as military fields.

Source: Linde Co., Div. of Union Carbide Corp.
New York, New York
For your copy: Circle No. 152 on Inquiry Card

Low Density Polyethylene Foam For Impact Packaging

A flexible, low density polyethylene foam has been placed on the market in limited quantities by The Dow Chemical Company as "an important addition" to its line of foamed plastics. The density is about two pounds per cubic foot—or 30 times lighter than water.

Development engineers say that flotation, fabricated industrial parts such as gasketing, packaging, and thermal insulation, appear to be among major fields of application. Because the polyethylene foam displays high shock absorbing ability, Dow says it has good potential in impact packaging applications. The material is easily fabricated with conventional woodworking or power tools. Other characteristics include: low water absorption and low moisture vapor transmission rates, high solvent and chemical resistance at room temperature, light weight, good insulation value. Dow Chemical Co., Midland, Mich.

Circle 230 on Inquiry Card

New Fiberglas Tape

The development of a brand new thermal curing, pressure-sensitive Teflon impregnated fiberglas tape is now available from Connecticut Hard Rubber Co.

In electrical applications, Temp-R-Tape TGV will meet Class C temperature requirements. It can be used as a bundling tape under clamps to provide convenience in application, as a splicing tape for high temperature wire and as a residual glass insulating layer should the Teflon and adhesive burn out at temperatures peaking over 700 F.

In mechanical applications, the Teflon fiberglas backing provides good wear resistance and dimensional stability at high temperatures. It is recommended as a non-stick surfacing for heat-sealing bars on packaging machinery, or as a low-friction or non-stick facing in other areas subject to wear or destructive accumulations.

Once the new tape is cured, it will resist the tendency to creep under load. It has a temperature range of −100 F to 500 F, and will adhere to any dry, clean surface.

Source: Connecticut Hard Rubber Co.
New Haven, Conn.
For your copy: Circle No. 153 on Inquiry Card

Metal-Ceramic Resistance Elements Stable Up To 500C

A major breakthru in resistance element design has resulted from a unique process which fires a metal resistance path onto ceramic at temperatures exceeding 600C. Because the element is very stable to 500C, it is extremely reliable at elevated temperatures. Current data indicates a temperature coefficient under 250 PPM/°C over a range of −63C to +150C. Resistance range is from 10 ohms to 100K ohms per square. Designed for higher wattage ratings at elevated temperatures, ceramic bases can be made in a wide variety of shapes and sizes. Chicago Telephone Supply Corp., Elkhart, Indiana.

Circle No. 257 on Inquiry Card

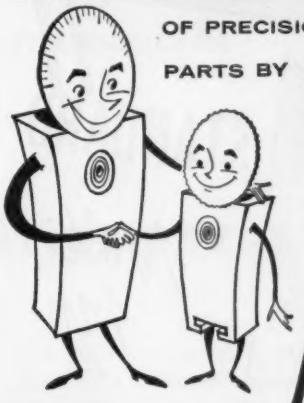
Silicone Coated Glass Cloth

Five new bulletins describe woven-glass-base insulating tapes and fabrics: properties and applications of glass tapes, fabric sheets, wrappers and die cut pieces, both silicone-varnished and rubber-coated.

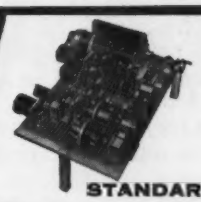
Source: Continental-Diamond Fibre Corp.
Newark, Delaware
For your copy: Circle No. 151 on Inquiry Card

TWO COMPLETE LINES

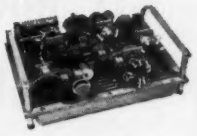
OF PRECISION SERVO-MECHANICAL PARTS BY Reeves



for prototype or production assemblies



STANDARD



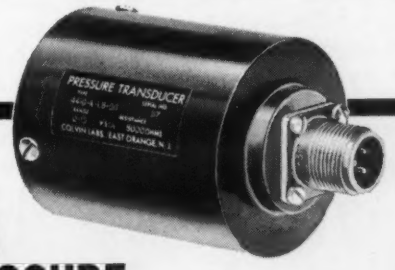
MINIATURE

New miniature series, ⅛" shaft, adapted to low-inertia, 400-cycle assemblies. Both lines include shaft hangers, dial assemblies, limit stops, differentials, couplings, etc., and a full range of Class II precision gears.

Send for new, complete, detailed catalog.

REEVES INSTRUMENT CORPORATION
A subsidiary of Dynamics Corporation of America
4RV59 Roosevelt Field, Garden City, New York
ENGINEERS: Rewarding employment opportunities at Reeves.

CIRCLE 28 ON INQUIRY CARD



COLVIN
HI-G PRESSURE TRANSDUCERS

- For Absolute, Differential or Gage Pressures.
- Small Size — Light Weight.
- Withstand 25g to 2000 cps.
- Outputs Linear With Pressure, Air Speed and Altitude.
- Accurately Dependable for Missile and Other Airborne Pressure Measurement Applications.

For complete technical information, write:

COLVIN LABORATORIES, INC.
364 Glenwood Avenue, East Orange, N. J.

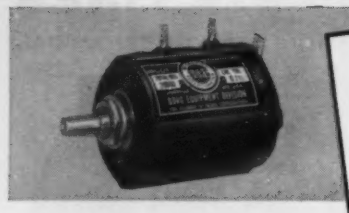
CIRCLE 29 ON INQUIRY CARD

STANDARD COMPONENTS

built by **BORG**®

FIT MANY SPECIAL DESIGN NEEDS

Design flexibility of standard Borg components often eliminates the need for expensive, specially designed units. Borg offers a complete line of precision potentiometers, turn-counting dials and fractional horsepower motors. Many of these standard Borg components are currently on duty in missile launching platforms and firing control stations, radar and sonar equipment, computers and similar electronic apparatus. Production of standard Borg components assures quick delivery. A partial selection is shown on this page. Write for complete data on all Borg components. Ask for catalog BED-A90.



205 SERIES, 10-TURN MICROPOTS

SIZE: 1¾" dia.; 2⅛" long; shaft extension ⅞" or special to order.

LINEARITY ACCURACY: ±0.1% and 0.05% (independent or zero based).

RESISTANCES: 50 ohms to 100,000 ohms, tolerance ±5%.

POWER DISSIPATION: 5 watts at 40° C.

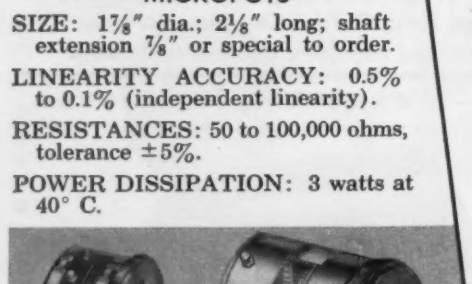
1100 SERIES, 10-TURN MICROPOTS

SIZE: 1⅞" dia.; 2⅛" long; shaft extension ⅞" or special to order.

LINEARITY ACCURACY: 0.5% to 0.1% (independent linearity).

RESISTANCES: 50 to 100,000 ohms, tolerance ±5%.

POWER DISSIPATION: 3 watts at 40° C.



900 SERIES MICROPOTS

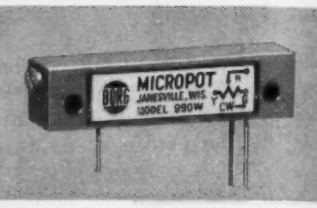
Borg 900 Series Micropots are available in single-turn, 3-turn and 10-turn models.

SIZE: Single-turn — 2" dia.; 1⅝₄" long
3-Turn — 2" dia.; 1⅜" long
10-Turn — 2" dia.; 2 1/16" long
Shafts — ¼" dia.
Bushing Mount — ⅞" long
Servo Mount — ⅝" long

LINEARITY ACCURACY: Single-turn — ±.5% (independent)
3-Turn — ±0.1% (independent, zero based, or absolute reference).
10-Turn — .05% (independent, zero based, or absolute reference).

RESISTANCES: Single-Turn — 50 to 50,000 ohms
3-Turn — 15 to 60,000 ohms
10-Turn — 50 to 300,000 ohms

TEMPERATURE LIMITS: Tested to 350° F.



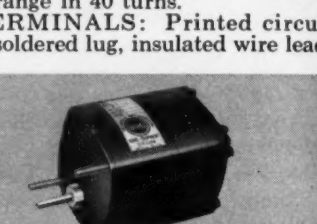
990 SERIES TRIMMING MICROPOTS

SIZE: 1¼" x 5/16" x 17/64"

RESISTANCES: 10 to 30,000 ohms standard. Other values on special order.
Tolerances — ±5% 100 ohms and over
±10% below 100 ohms

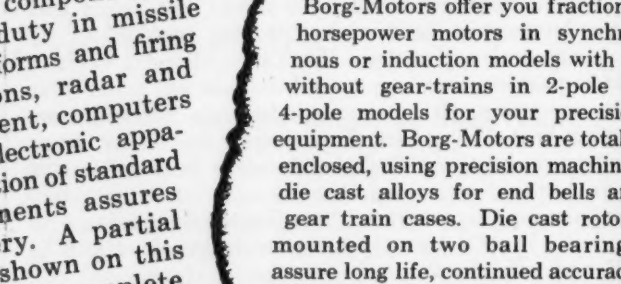
ADJUSTMENT: Screw driver slot provides adjustment of complete range in 40 turns.

TERMINALS: Printed circuit, soldered lug, insulated wire leads.



PRECISION INSTRUMENT MOTORS

Borg-Motors offer you fractional horsepower motors in synchronous or induction models with or without gear-trains in 2-pole or 4-pole models for your precision equipment. Borg-Motors are totally enclosed, using precision machined die cast alloys for end bells and gear train cases. Die cast rotors, mounted on two ball bearings, assure long life, continued accuracy.



DIRECT READING MICRODIALS

Borg Direct-Reading Microdials provide the highest accuracy of perception when forced-fast-reading and setting is required because of their inline digital presentation. Borg Direct-Reading Microdials are available in 3-digit 10-turn models, 4-digit 100-turn models and 5-digit 1,000 turn models. Also available are Borg Concentric Scale Microdials which indicate the position of any multi-turn device of 10 turns or less.

WRITE FOR COMPLETE DATA ON ALL BORG COMPONENTS — CATALOG BED A90

BORG EQUIPMENT DIVISION
Amphenol-Borg Electronics Corporation
JANESVILLE, WISCONSIN

BORG®

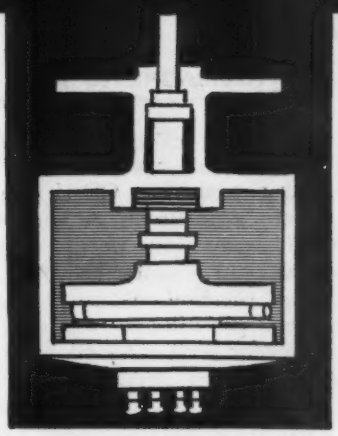
- MICROPOTS
- MICRODIALS
- MOTORS

CIRCLE 30 ON INQUIRY CARD

COMPONENTS DIGEST 3—PART 3

ELECTROMAGNETIC AND POTENTIOMETER TRANSDUCERS

Part 1 of Components Digest 3 appeared in the February 1959 issue.
Part 2 appeared in the March 1959 issue.



VERY LOW TORQUE POTENTIOMETERS

Among the simplest of pick-off devices are the very low torque potentiometers. Friction in rotary devices of this type can be reduced to a minimum of the order of several thousandths of an ounce-inch. Potentiometers are discussed generally in CD-II. CD-III considers those aspects of potentiometer performance especially related to pick-offs.

To achieve very low torque as well as sensitivity over small displacement ranges, fine wire must be used for the resistance element. Fine wire provides good resolution and reduces starting friction and wire-hopping, which occur when few turns of heavy wire are used. Engineers at Ace Electronics Associates, Somerville, Mass., point out that equally important as size of wire is winding technique as it effects wire lay and continuity of spacing. Maintaining uniform wire tension when winding is a critical necessity. Rectangular cards, for example, are more difficult to wind than arbors because the edges do not provide as smooth a surface and the tension is extremely difficult to control.

Low contact pressure is also essential for low friction applications, but unfortunately this leads to vibration sensitivity and high contact noise. According to Louis Berni, Ace Electronics' Chief Engineer, normal contact pressure to keep noise low is 8 to 10 grams of deflected spring pressure. To keep the torque low, he says, contact pressure might have to be reduced to 2 to 5 grams. And with such low contact pressure the formation of any kind of surface condition—caused by oxidation, moisture crystallization at low temperatures, or synthesis of organic compounds from organic vapors—imposes a severe obstacle since the contact has difficulty in scrubbing the coating from the wire.

Selection of materials for the winding and contact for low pressure operation is a very important aspect of design. Use of precious metals has been the solution in most cases, Mr. Berni says, but they must be used in the right combination. He warns that precious metals generally have a higher coefficient of friction—as much as 50% higher—which tends to increase the inherent friction between winding and contact. Another very important factor, he says, is that precious metals are more malleable and subject to cold working and deformation leading to shorting out of adjacent wire windings.

Vibration sensitivity and resonance are inextricable factors in contact design. To minimize these effects, Ace uses a one-piece triangular shaped contact that is dynamically stable, has a natural resonance frequency too high to cause difficulty, and offers negligible inertia to acceleration forces.

Depending upon the application, potentiometer pick-offs may take a variety of forms. These include the conventional rotary type, almost always of the single turn variety, linear motion devices with ranges extending from a small fraction of an inch to many feet, sector potentiometers which cover a limited angular range, as well as other specialized forms. For small displacements, carbon and metal film units provide infinite resolution.

Ball Bearing units are useful for applications permitting friction to 0.01 to 0.02 oz.-inch while jewel bearings are used where much lower friction is required. Ace engineers point out the importance of making sure the ball bearings are "dry". In checking units out on environmental tests, they have found that the viscosity of the grease normally in the bearing increases at −55°C and raises the torque required considerably. When they removed the grease they had no further difficulty.

Jewel bearings don't have that kind of problem at low temperatures and operate with 25 to 40% less friction. With use of ball bearings, alignment is more critical since both inner and outer races have to register and the action of the balls rolling and the slippage introduce some inertia.

Manufacturing techniques and mechanical tolerances have substantial effect on the electrical performance (such as linearity) and life in addition to their obvious influence on friction and torque. Low friction performance of jewel bearings is dependent on how these bearings are mounted —concentricity, parallelism, etc. Shaft bearing surfaces have to be properly burnished. Ace engineers state that by encasing both end jewel bearings in a single bushing, aligning, and machining through with an allowance of 0.0003″ total indicator reading on concentricity and 0.0002 on misalignment, both electrical and mechanical performance will be satisfactory. To properly measure the tolerances on face run out and concentricity of body to the shaft, they recommended that the shaft be fixed and the body rotated.

Often the resistance element and slider assemblies are directly mounted to the elements whose relative motion is being measured. Absence of additional supports completely eliminates bearing friction of the pick-off element.

No discussion of very low torque potentiometers would be complete without commenting on how this very low torque is measured. Ace engineers contend there is no standard available mutually accepted by the industry. Precalibrated spring devices are not capable of high accuracy at "very low torque" levels where there errors perhaps range to 25 to 50%. Such devices are suspectible to temperature changes and fatigue. Care must be taken that the method of determining torque does not contribute forces of moment or thrust, etc., that would make the determination invalid.

Life of very low torque potentiometers is another important consideration. Even where use is of short duration, testing for reliability calls for an adequate life. Mechanically, low torque pots by virtue of low gram contact pressure have inherent longer life. Electrically, life is inherently shorter, however, because of the deformation of the precious metal wire windings and their consequent shorting out and also because of the limited pressure to push off the surface films and the consequent noise build up.

With the right compromise in reliability, speed, noise, etc., very low torque potentiometers are being manufactured for gyro, and critical servo applications and for remote indicator and fine instrument read-out; mostly for commercial and laboratory work. Current limitations are

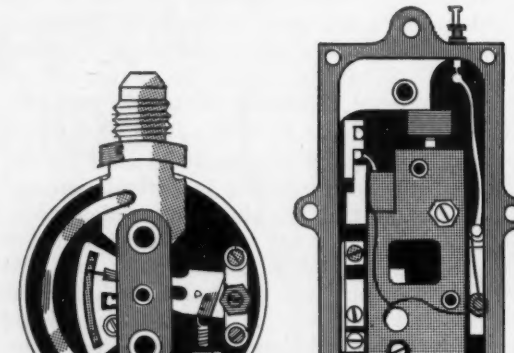
much more restrictive than those of voltage because of the light contact pressure.

As described in CD-II, the potentiometer is an exceptionally versatile device where nonlinear functions of slider motion are required. Taps may be brought out for external padding to permit convenient setting of an empirical nonlinear function. Where torque is of less consequence, ganged potentiometers provide multiple outputs. Compensation for fixed output load may be designed directly into the resistance element by the potentiometer manufacturer. The applicability of the resistance potentiometer to either a-c or d-c signals is a major advantage.

LINEAR MOTION POTENTIOMETERS

Quite distinct from low torque potentiometers are the linear motion types which are available in displacements up to many feet. The same basic principles of resistance potentiometers apply to linear motion units as to more conventional types. For example, accuracy and resolution are functions of the length of resistance elements, noise contact pressure, etc. Some types are available that permit misalignment between slider shaft and resistance element to facilitate assembly. For small motions, film type units are recommended.

TRANSDUCERS EMPLOYING INDUCTIVE AND POTENTIOMETER TYPE PICK-OFFS.



The pick-offs described in this Digest are often combined with additional transducing elements to constitute a pick-up with an electrical signal output. Typical are pressure pick-ups and acceleration pick-ups.

Accelerometers

A mechanical accelerometer consists of a mass supported from a frame by a spring and an electrical pick-off to measure its position. The displacement of the mass with respect to the frame is a measure of acceleration. Damping necessary to secure satisfactory response, may be provided electrically or mechanically. Sealing the assembly in a fluid of suitable viscosity and insensitivity to temperature is a simple damping technique. Accelerometer response is accurate only for inputs appreciably slower than the natural frequency. The transfer function of an ideal accelerometer of this type, neglecting friction, nonlinearity of the spring constant, and pick-off, is

$$\frac{\text{Output}}{\text{Input}} = \frac{K_s/\omega_n^2}{(s/\omega_n)^2 + (2\delta/\omega_n)s + 1}$$

where K_s is the sensitivity of the pick off.
ω_n is the natural frequency, rad/sec.
s is the Laplace complex variable
δ is the damping factor

Accelerometers employing stiff springs have a wider acceleration range and a higher natural frequency. Doubling spring stiffness multiplies the full-scale range by an equal factor, and natural frequency by $\sqrt{2}$. For the same damping factor response, the damping must be increased by $\sqrt{2}$, although less damping may be necessary at the higher natural frequency where the settling time is greatly reduced. For maximum useful band-width, a damping factor of about 0.7 is used. Increased damping decreases the response peak in the neighborhood of the natural frequency, minimizing transient oscillations due to high frequency excitation.

Accelerometers are frequently employed as part of a servo loop to achieve highest accuracy. In such applications, a precise torque or force generating device, such as a Microsyn torque generator, is required. No spring is necessary. The pick-off is balanced at null for the case of zero acceleration. Any displacement of the moving mass from null results in an output signal voltage which is amplified and applied to the torque unit. At equilibrium, the output of the torque unit exactly balances the acceleration force and its input is a direct measure of acceleration.

This closed loop arrangement substitutes a precision torque unit for a precision spring. The accuracy of the pick-off is no longer a factor, it being only required to develop a stable noise-free null signal of high sensitivity, and not to introduce excessive friction. Accuracy is limited primarily by the accuracy of the torque generator.

Damping is introduced electrically in accordance with prior art in servomechanisms of this type. A high natural frequency can be achieved since natural frequency is proportional to the square root of loop gain. Instruments of this type, with a carefully made temperature compensated torque unit, can be made to measure accelerations of the order of 0.001g with accuracies of about 10 times those obtainable with open loop accelerometers.

Pressure Transducers

Pressure transducers are used in a variety of applications —air-speed and mach number, altitude, absolute and differential pressures, temperature, etc. They may be employed, as with the accelerometers described above, in either open-loop or closed loop devices.

Basic transducer elements are the Bourdon tube, in one form or another, the expansion bellows and diaphragms. Each of these devices generates a force (or displacement, if unconstrained) depending on the difference between internal and external pressure. The displacement transducer

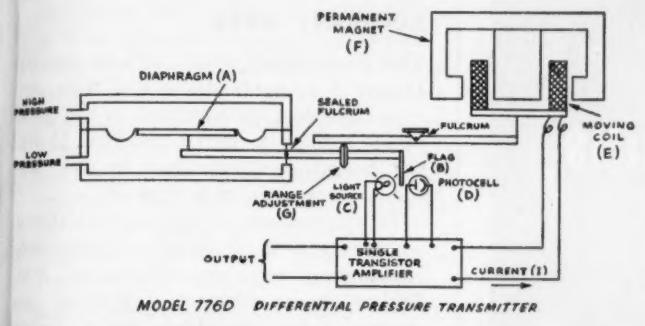


Fig. 16.1-GPE Controls' Differential Pressure Transmitter. Differential pressure applied across diaphragm (A) causes the lever arm to position flag (B) with respect to the light source (C) and the photocell (D). The resulting signal from the photocell is fed to the single-transistor amplifier. The amplifier output, consisting of a dc current (I) proportional to the photocell output, flows through the moving coil (E) in the field of the permanent magnet (F). The moving coil is attracted by the magnetic field of the permanent magnet with a force proportional to the current (I). This force is transmitted through the balance arm to the range adjusting wheel (G), which, in turn, applies a force to the lever arm to balance the force exerted on the lever arm by diaphragm (A). Thus, differential pressure across the diaphragm is measured by the current (I). Therefore, current (I) is a direct measure of pressure difference. Current (I) is converted into the output voltage signal, in the range of 0-25 volts dc. The range adjustment wheel (G) is threaded to the lever arm and may be moved to set the desired range. An additional vernier adjustment (not shown) is provided in the electrical circuit.

combines with a pick-off to form a measuring device with an electrical signal output.

Pressure transducer errors are of the general error pattern described previously. They comprise errors in the pressure sensing element, and errors in the pick-off. The principle error categories are: Linearity or conformity, repeatability, hysteresis, resolution, dead band (pressure change required to give discernible change in output), scale factor, and dependence on environment, particularly temperature.

Acceleration may introduce inaccuracies. These may be handled by careful balancing and use of stiffer bellows. Unfortunately, balancing can never be completely satisfactory, and increased stiffness results in a loss in sensitivity. Transducers designed for high pressures and high natural frequency naturally resist acceleration effects better, because of their greater stiffness.

Where resistance-type pick-offs are used, contact pressures are very light for minimum hysteresis and deadband. This may lead to poor electrical contact in the presence of shock and vibration.

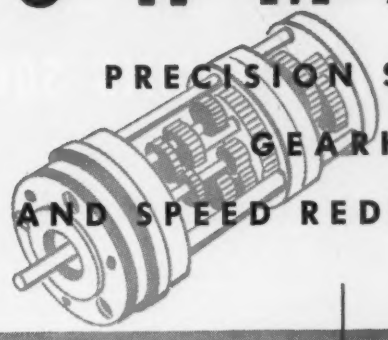
Volume of fluid involved in actuation of the pressure transducers may be a limiting factor in the natural frequency. Expansion and compression of the fluid, including that in the lead-in lines, under dynamic conditions, delays the response of the pressure transducers to changing input conditions and markedly changes the transfer function. When closed loop (force-balance) operation is used excessive fluid volume may lead to instability.

In a manner analogous to that described for accelerometers, pressure transducers may be used in force-balance closed-loop circuits. As before, the principle advantage is elimination of error due to nonlinearity of the pressure sensing element.

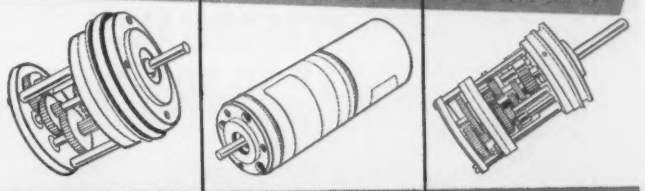
Figure 16.1 shows a force-balance system for sensing differential pressure, as devised by GPE Controls, Inc.

BOWMAR

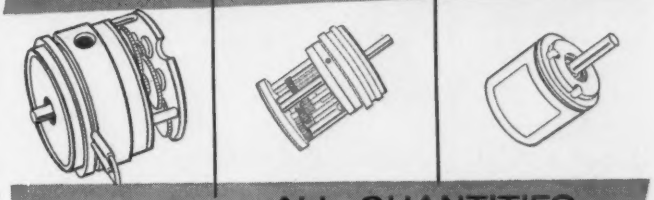
PRECISION SERVO GEARHEADS AND SPEED REDUCERS



ALL TYPES

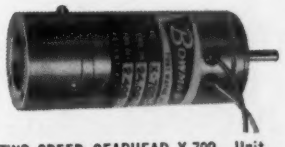


ALL SIZES

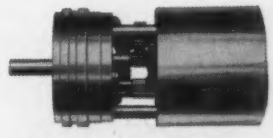


ALL QUANTITIES

Bowmar designs and manufactures all types of precision geared components, assemblies and packages for all types of precision control systems. Dozens of semi-standard speed reducer and gearhead sizes are offered in most ratios; but these types may be altered, or entirely new types can be developed to fit new requirements. Typical of many Bowmar designs currently being manufactured ——

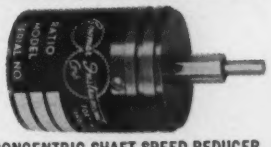


TWO SPEED GEARHEAD X-709. Unit shown has speed reductions of 2400:1 and 24000:1 for fast approach and slow zeroing. Unit is electrically actuated and is completely self contained. Typical of many Bowmar designs currently being manufactured.



PRECISION SERVO MOTOR GEARHEAD 750-GH (with housing). Standard ratios to 2000:1; Starting torque: .005 in.-oz.; Load torque: 5 in.-oz.; Backlash: 30 min. max.; Diameter: .750 in. Typical of many Bowmar designs currently being manufactured.

PRECISION MINIATURE SPEED REDUCER 1062. Standard ratios to 4000:1. Starting torque: .005 in.-oz.; Load torque: 25 in.-oz.; Backlash: 45 min. max.; Diameter: 1.062 in. Typical of many Bowmar designs currently being manufactured.



CONCENTRIC SHAFT SPEED REDUCER X-530. Single ended unit has optional internal slip clutch set to customer requirements. Most ratios available. Starting torque: .01 in.-oz.; Backlash: 30 min. max.; Diameter: 1.062 in. Typical of many Bowmar designs currently being manufactured.

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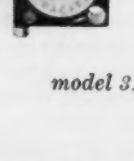
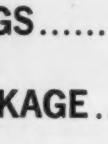


model 318



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HIGH POWER RATINGS..... 1-watt at 95°C; 0.5-watt at 150°C.

SUBMINIATURE PACKAGE..... ½-inch square, aluminum case.

The Series 313 Squaretrims are the smallest, high-temperature, trimming potentiometers. The Series 318 Squaretrims are identical in performance to the Series 313, but they are adapted to mount base-down to a printed circuit board and remain secure under high vibration and shock loads. Both are available in humidity proof versions. For full environmental specifications, write for Data File EL-653-1.

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CIRCLE 32 ON INQUIRY CARD

SUMMARY DATA

This concluding portion of Components Digest 3 presents numerical data and manufacturers' information on the pick-offs described in Part I and Part II and the transducers described in the previous sections of this Part III.

In the review of commercial items, no attempt is made to provide complete coverage of each manufacturers' line. Rather, items of special interest are stressed, the standard units being widely available. Examples referring to specific manufacturers illustrate typical data on good designs.

DIFFERENTIAL TRANSFORMERS

These devices generate an output voltage proportional to the linear displacement of a magnetic core from a null position. The operating basis is essentially that of a transformer with variable coefficient of coupling. Accuracies to 0.1%, low null voltages, and a wide range of displacements characterize the commercial types. The principal deficiency is the relatively high ratio of overall length to length of stroke for linear output. Temperature error is relatively difficult to control in high accuracy applications.

Differential transformers are extremely flexible, may be rescaled for a wide range of input and output voltage levels and frequencies (although operation improves generally with frequency), and, by proper design and selection of materials, may withstand extreme temperature.

The listings in Table I are intended to give a picture of current commercial quality and available types. There are no widely accepted standards. In every instance the manufacturer's line is far broader than indicated by the Table and appropriate inquiries will usually reveal some already-developed unit suitable for a new requirement.

The listing, for comparison purposes, includes only linear motion types. A variety of rotary input types, similar in function to induction potentiometers are also available. American Electronics describes a "brushless induction potentiometer", which is essentially a variable coupling transformer. Because there is no reluctance change with angular position, the device exhibits no coercive magnetic torques. Size 15 accuracy is announced as to 1% over a ±30-35 degree range. Phase shift is of the order of a couple of degrees, and null voltage to about 0.1%. Crescent Engineering's 1⅝-inch-diameter rotary transducer exhibits a linearity of ±0.5% over ±30 degree range with a 3 kc input.

Synchros and resolvers were described in Part One of Components Digest 3. This section summarizes the performance characteristics of available commercial types for transducer application. Emphasis is primarily on their use to measure small angular displacements, rather than the major function of remote angle transmission.

Errors due to scale factor variation from unit to unit and with temperature, frequency, excitation voltage level and loading have already been described. Standard BuOrd-type synchros, widely available, are not discussed here. The presentation is principally concerned with late or unusual developments as described by the manufacturers.

The most significant trend in synchro development has been in miniaturization, while still maintaining excellent accuracy. Four hundred cycle, size-8 synchros are currently available from a number of sources. Because of the small size and low voltages of these units, Clifton Precision Products Co. in particular is emphasizing this frame size. Induction Motors, Inc. has recently added a size-8 line through its West Coast division. 26 volts, say, are preferred as standard ratings, rather than 115 volts. Accuracies are typically of the order of ±7 minutes over the angular range, meaning much higher accuracies over the limited angular travel of many transducer applications.

Interestingly enough, the special skills acquired during the development of sub-miniature synchros have subsequently been re-applied to the larger sizes to achieve vastly improved accuracy. Particularly notable has been Kearfott's line of high accuracy size 25 synchro resolvers (4-wire synchros) with accuracies to *20 seconds*. According to the manufacturer, data transmission systems employing three of these synchros have errors of less than 36 seconds. The obvious application is as a substitute for two-speed synchro transmission systems with the resulting circuit simplifications, and elimination of much gearing. In the same diameter, but a good deal shorter, Kearfott and Norden-Ketay feature "pancake" synchros, with accuracies to 1 minute.

American Electronics has recently announced a temperature compensated size-8 resolver, with an accuracy of the order of 0.1% and exceptionally low null voltage. This unit may be applied where a precise scale factor is required over a wide temperature range in a miniature component. A compensation amplifier is required.

Many manufacturers have an-

POSITION TRANSDUCERS by BOURNS

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3. Self-aligning Model 157; noise-free operation at 40G; 2000 cps.
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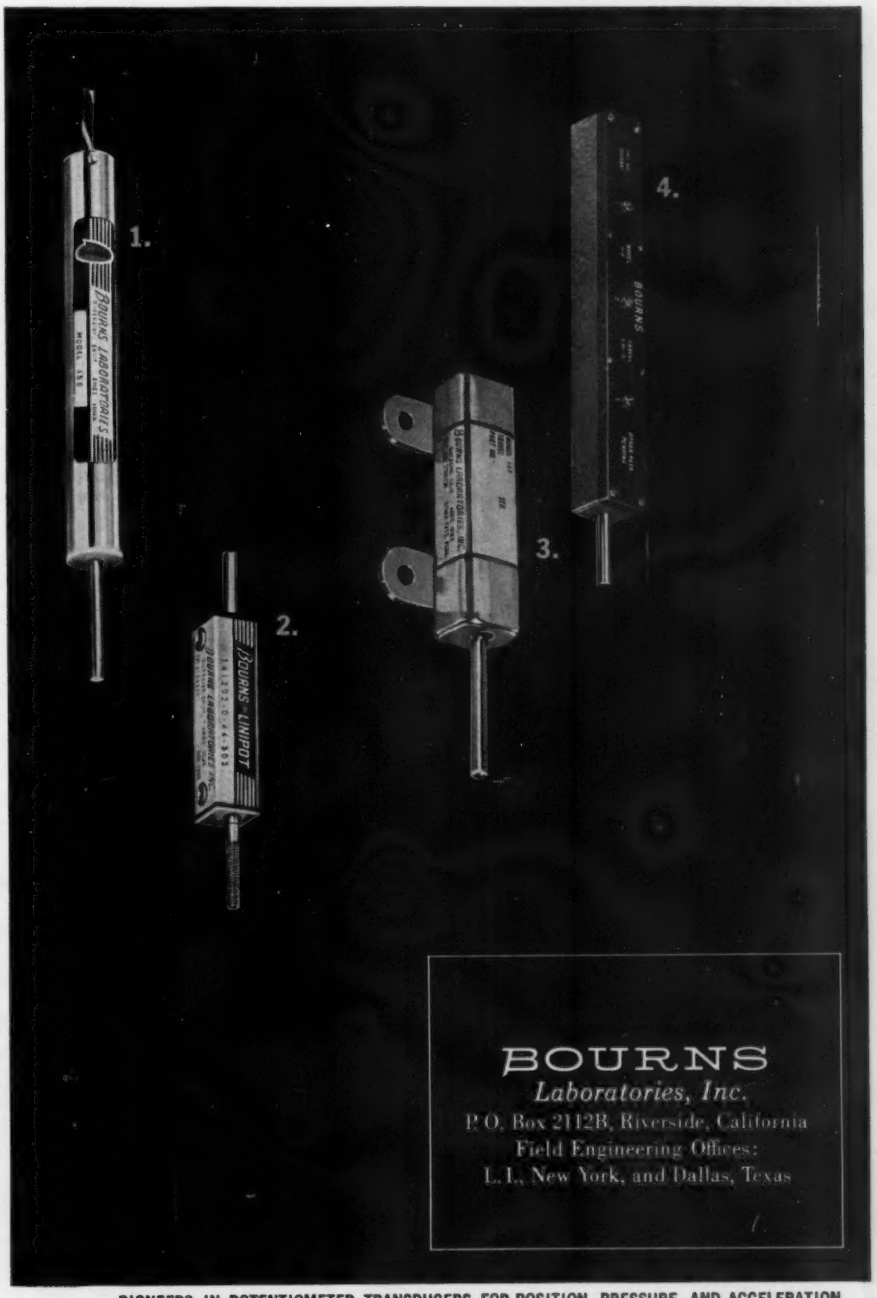

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CIRCLE 33 ON INQUIRY CARD

TABLE 1.
SUMMARY OF LINEAR DIFFERENTIAL TRANSFORMER CHARACTERISTICS

1.	Manufacturer	Atcotran	Atcotran	Atcotran	Atcotran	Atcotran
2.	Type or Model No.	6205	6206	6207	6208	6208-K SKF A-5602
3.	Coil or Bobbin Length (inches)	16	4 3/8	1/2	2	
4.	Coil or Bobbin Diameter (inches)	7/8	7/8	7/16	7/16	7/8
5.	Stroke (± inches) -	2.5	0.5	0.01	0.15	0.030
6.	Excitation (Volts/cps)	/60	/60	/60	/60	3/60
7.	Sensitivity (MV/Mil/volts)	0.005	0.032	0.055	0.185	4
8.	Null Output	0.2 mv/volt in	Negligible	0.05 mv/volt in	Negligible	
9.	Output Impedance (Ohms/cps)					
10.	Loading (Ohms)					
11.	Linearity (±%)	1	0.5	0.1	0.1	
12.	Remarks	Available to 500° F	Available to 500° F	Available to 500° F	Available to 500° F	Experimental unit. Miniature length

1.	Manufacturer	Atcotran	Collins	Collins	Collins	Collins
2.	Type or Model No.	6208-MHK A-93910	LMT-10910	LMT-23603	LMT-92401	LMT-93304
3.	Coil or Bobbin Length (inches)	2	4 3/8	13 5/8	3	9
4.	Coil or Bobbin Diameter (inches)	1 1/4	3/8	5/8	5/8	5/8
5.	Stroke (± inches)	0.1	1	3	1/2	3 1/2
6.	Excitation (Volts/cps)	6/60	6.3/400	26/400	6.3/400	26/400
7.	Sensitivity (MV/Mil/volts)	0.5	0.8	0.077	1.5	0.154
8.	Null Output	3 mv at 6 v, 60 cps				
9.	Output Impedance (Ohms/cps)					
10.	Loading (Ohms)					
11.	Linearity (±%)		1/2	1/2	1/2	1/2
12.	Remarks	Experimental unit, explosion proof, radiation resistant	Uniform input and output impedance with core displacement	Temperature −90 F to −400 F. Uniform input and output impedance with core displacement	Temperature −90 F to −1200 F. Uniform input and outputimpedance with core displacement	Temperature −40 F to −1200 F. Uniform input and output impedance with core displacement

1.	Manufacturer	Daytronic	Dynamic Measurements	IRC	IRC	IRC
2.	Type or Model No.	103	200	70-3151	70-3155	70-3061
3.	Coil or Bobbin Length (inches)	1 3/4	2 1/2	1 7/32	1	3/8
4.	Coil or Bobbin Diameter (inches)	1/2	1	3/8	3/8	5/16
5.	Stroke (± inches)	0.040	±5 turns	0.005	0.100	0.005
6.	Excitation (Volts/cps)	3.0/400	12/400	/60	/60	/400
7.	Sensitivity (MV/Mil/volts)	0.7	1.5/turn	0.7	1.0	0.4
8.	Null Output		10 mv	0.25%	0.25%	0.25%
9.	Output Impedance (Ohms/cps)	210/400	2000/400			
10.	Loading (Ohms)		7000 for zero phase shift			
11.	Linearity (±%)	0.5		0.25	0.25	0.25
12.	Remarks	Operable over wide frequency range	Rotary input, screw actuated	Magnetic shield	Magnetic shield	Miniature, stainless steel case

1.	Manufacturer	Minatron	Minatron	Minatron	Schaevitz	Schaevitz
2.	Type or Model No.	Lyn-500-D	Lyn-1000-D	Lyn-3000-D	005MS-L	020MS-L
3.	Coil or Bobbin Length (inches)	4 1/8	6	13	17/32	19/32
4.	Coil or Bobbin Diameter (inches)	3/4	3/4	3/4	3/8	7/16
5.	Stroke (± inches)	0.500	1.000	3.000	0.005	0.020
6.	Excitation (Volts/cps)	15 Max/60	15 Max/60	15 Max/60	3/2000	3/2000
7.	Sensitivity (MV/Mil/volts)	1.5	1.3	0.9	1.88	3.54
8.	Null Output				0.5%	0.5%
9.	Output Impedance (Ohms/cps)					
10.	Loading (Ohms)					
11.	Linearity (±%)	1/2	1/2	1/2	0.5	0.5
12.	Remarks	Standard line	Standard line	Standard line	Hi-temperature version available; miniature shielded	Hi-temperature version available; miniature shielded

TABLE 1. Cont. SUMMARY OF LINEAR DIFFERENTIAL TRANSFORMER CHARACTERISTICS

1.	Atcotran	Atcotran	Atcotran	Atcotran	Atcotran	Atcotran
2.	6208-K B.L.H.	6208-K A-12294	6208-K A-72689 A-72089	6208-K A-9710	6208-K A-82433	6208-K A-96305
3.	2	2 1/2		3		3 9/16
4.	1 1/16	7/8	1 5/16	1.32		2 3/16
5.	0.1	0.63	0.2	0.125	0.15	0.2
6.	5/2000	12.5/2500	110/800	120/400	3/60	115/60
7.	0.11	0.5	3.5	1.3	0.18	0.25
8.	6 mv	15 mv	200 mv	40 mv	1 mv at 3.2 v, 60 cps	20 mv
9.						
10.						
11.						
12.	Experimental unit, 1000° F	Experimental unit. Large motion, uniform phase angle	Experimental unit. Hi output, large actuating force	Experimental unit. High voltage	Experimental unit. Explosion proof, lo-intensity radiation	Experimental unit. Radiation resistant

1.	Collins	Collins	Collins	Collins	Daytronic	Daytronic
2.	LMT-00500	LMT-00800	LMT-01200	LMT-01400	101	102
3.	3	4 1/2	8	10	5 3/16	3 3/8
4.	3/8	3/8	3/8	3/8	1 1/8	1 1/8
5.	3/8	1	2	2 1/2	0.190	0.060
6.	8 Max/400	9 Max/400	14 Max/400	18 Max/400	6.3/400	6.3/400
7.	0.7	0.4	0.2	0.2	1.6	2.8
8.	1/4%	1/4%	1/4%	1/4%		
9.					5000/400	1200/400
10.						
11.	1/2	1/2	1/2	1/2	0.5	0.5
12.						

1.	IRC	IRC	Minatron	Minatron	Minatron	Minatron
2.	70-3063	70-3145	Lyn-4-100	Lyn-003-SM	Lyn-020-SM	Lyn-050-D
3.	7/16	1	1	15/64	27/64	1 3/8
4.	5/16	7/16	1/2	15/16	27/64	3/4
5.	0.020	0.100	0.100	0.003	0.020	0.050
6.	/400	/400	12 Max/400	5 Max/2000	5 Max/2000	15 Max/60
7.	0.5	1.5	3	2.5	2.5	1.5
8.	0.25%	0.25%				
9.						
10.						
11.	0.25	0.5	1/2	1/2	1/2	1/2
12.	Miniature, stainless steel case	Miniature, magnetic shield		Sub-miniature model	Sub-miniature model	Standard line

1.	Schaevitz	Schaevitz	Schaevitz	Schaevitz	Vinson	Vinson
2.	100MS-L	033SS-L	100SS-L	1000SS-L	RC-3-10	RB-04-10
3.	59/64	1 1/8	1 13/16	7 7/64	1-18	4-18
4.	7/16	13/16	13/16	13/16	5/8	5/8
5.	0.100	0.033	0.100	1.000	0.2-8.5	1.8-8.5
6.	3/2000	6.3/60	6.3/60	6.3/60	5-26/3000	26/400
7.	3.00	1.30	1.35	0.15	7-0.1	0.5-0.1
8.	0.5%	0.5%	0.5%	0.5%		
9.						
10.						
11.	0.5	0.5	0.5	0.5	1	1
12.	High temperature version available; miniature shielded	60 cycle units, shielded	60 cycle units, shielded	60 cycle units, shielded	Describes complete line, −400° F to +1200° F	400 cps systems −100° F to +500° F

nounced high temperature synchros. Beckman Helipot indicates a line of 7-minute-accuracy size-11 units, operable in the temperature range from −60C to +200C. Kearfott lists a 200C, size-8 unit. John Oster has advertised a 450F synchro. Probably a lot remains to be learned about accuracy, axis shift, scale factor variation over such broad ranges, and of course, life at these elevated temperatures. In particular, axis shift as a function of temperature is a major error in limited-angular-travel transducer applications.

In the more specialized areas, Lear describes 10-minute "pancake" synchros with interchangeable rotors and stators. These may be designed directly into aircraft instruments as component parts, using the instrument frame itself as a structural member. Norden-Ketay shows a dual size 11 combining 2 synchros in a common frame, with an electrical zero differential not exceeding 10 minutes.

INDUCTION POTENTIOMETERS

These rotary devices are based upon varying the coefficient of coupling between a primary and secondary winding. They possess the advantages of infinite resolution, long life at high speeds, and good accuracy for a limited rotation angle. On the other hand they are essentially a-c devices with errors due to phase-shift, harmonic generation, variable impedance with shaft rotation and sensitivity to input voltage and frequency variation.

Available accuracies approach 0.1% in a size 15 unit with a total angular excursion of ± 45 degrees. Muirhead's size-11 Linvar is of BuOrd-type construction with a maximum linearity error of ±¼% over an angular range of ±85 degrees. Kearfott announces similar performance. Induction potentiometers are frequently used with input booster amplifiers where units are cascaded and loading temperature errors must be compensated.

MICROSYNS

Microsyns, originally developed at MIT, differ from rotary differential transformers primarily in the details of design and performance. As a pickoff, the Microsyn possesses exceptional accuracy, considering its limited angular range, negligible magnetic reaction torques and an absolute minimum of friction. Sizes range from size 11 to size 25 in most instances, although Sterling Precision features a ⅞ inch diameter model. Table II provides typical performance data.

TABLE II

MICROSYN PERFORMANCE CHARACTERISTICS

Typical Data

frequency, cps	60	400	
Linearity, % of max. output	±0.5% to 7° ±1% to 10°	±0.5% to 7° ±1% to 10°	
Residual Null, Equiv. Degrees Rotation	0.01	0.01	
Friction, oz.-in.	to 0.001	to 0.001	Special request usually somewhat higher
Reaction torque, oz.-in.	neglig	neglig	Less than friction torque
Sensitivity, volts/°	¼	1-3	Depends on size

Boston Division, Minneapolis-Honeywell describes a bi-directional pickoff, a two-axis differential transformer providing electrical signals proportional to the magnitude and direction of translational displacement along X and Y axes. This is similar to a *linear motion* resolver, or coordinate converter. Linearities vary from ±4% to ±15% for small displacements.

TABLE III.

SUMMARY OF ACCELEROMETER CHARACTERISTICS

1. Manufacturer	Bourns Laboratories	Bourns Laboratories	Consolidated Electrodynamics	Fairchild Controls Corporation	Giannini	Giannini
2. Model No.	602A	605	4-260	TA-100	24113	24128
3. Range (g's)	2-20	0-1 to 0-10	Up to ±12	±1 to ±30	±1 to ±30	±1 to ±30
4. Natural Frequency (cps)	6-18	5-15	200 undamped, 140 damped	5-30	6-32	4.5 to 26
5. Pickoff	Resistance	Resistance	Magnetic	Resistance, or Magnetic	Resistance	Resistance
6. Linearity (±%)	0.75	0.6	1	1.5	1	1
7. Threshold Sensitivity (g's)	1-3% maximum acceleration	0.5-1.5% maximum acceleration	0.83% maximum acceleration		0.02 g	0.06 g
8. Remarks	Air damped, pressure sealed, lo-cross-talk	Air damped, pressure sealed, lo-cross-talk	Silicone damped. Lo-frequency acceleration measurements to 100 cps	Oil damping, damping factor uniform −55° C to +100° C. Linearity figure is for accuracy envelope	Magnetic damping, hi-sensitivity	Rugged, oil-filled, lo natural frequency

1. Manufacturer	Giannini	Giannini	Humphrey, Inc.	Humphrey, Inc.	Humphrey, Inc.	Pace Engineering Co.
2. Model No.	24142	24144	LA 03	LA15	LA17	A3
3. Range (g's)	±1 to ±40	±2.5 to ±30	±1	±1	−0.5 to +20	±0.1 to ±10
4. Natural Frequency (cps)	11 to 54.3	11.1 to 38.5	15	9	30	90 to 1000
5. Pickoff	Resistance	Resistance	Resistance	Resistance	Resistance	Magnetic
6. Linearity (±%)	2	1	2	1.5	2	0.5
7. Threshold Sensitivity (g's)	0.04 g					0.2% maximum acceleration
8. Remarks	Linearity included in 2% accuracy envelope, lo-cross-talk, high resolution	Very small, lo-cross-talk, extreme environments	For missile application, pressure sealed	Hermetic seal, for missile application	Hermetic seal, for missile application	Oil damping, lo-cross-talk, high natural frequency

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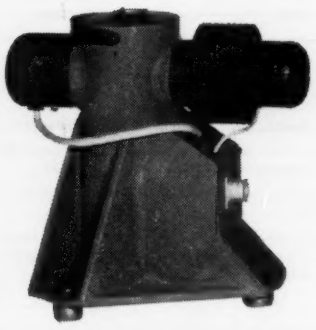
the facilities to produce it

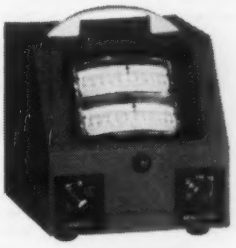
SPECIAL DEVICES*

FOR INDUSTRY, SCIENCE AND THE MILITARY



Sensing Unit

Amplifier



Indicator

Electronic Tilt-Angle Transducer

The K&E Tilt-Angle Transducer consists of the three units illustrated. The signal from the sensing unit is transmitted through the amplifier to the remote indicating unit by cable. A chart recorder can be used in addition to the indicator to provide a permanent record of the tilt changes in the structure, or the signal from the amplifier can be fed directly into a servo mechanism to make the system self correcting.

This ability to monitor and control tilt from a distance, combined with the ultra sensitivity of the unit, makes it possible to achieve alignment tolerances in radar axles, stable platforms, missile ground support equipment, and similar devices to a degree of accuracy heretofore impossible.

SPECIFICATIONS

ELECTRONIC TILT-ANGLE TRANSDUCER Sensing Unit

1. **Weight** — 16 lbs.
2. **Size** — 9" high x 7" wide x 6" deep.
3. **Range** — Sensing Unit can be supplied with a range from plus or minus 2.5 seconds to plus or minus 20 minutes to suit requirements.
4. **Sensitivity** — Varies inversely with the range; with a maximum sensitivity of 1/20 second of arc.
5. **Directional Response** — Senses amount and direction of angular tilt against true horizon in one plane. Sense of direction is retained through tilting range of plus or minus 90 degrees.
6. **Response** — Instantaneous.
7. **Drift** — Less than 1% in 24 hours after an initial warm-up of 30 minutes. For a plus or minus 2.5 second range instrument the drift would not exceed .025 seconds in 24 hours.
8. **Environmental Stability** — Sensitivity and calibration are stable through a temperature range of minus 40°F. to plus 120°F. Sensing Unit is dust and moisture proof.
9. **Acceleration Effects** — Sensing Unit will not read true angular tilt when accelerated; however, the pendulum axis of symmetry is marked to allow use of instrument on the rotational axis of shafts.
10. **Damping Characteristics** — Magnetic; time constant 0.4 seconds.
11. **Feed-Back Speed** — Optimum feed-back speed for servo-mechanism application is 150 seconds of arc per minute.

ELECTRONIC TILT-ANGLE TRANSDUCER Power Amplifier–Indicator Units

1. **Required Power Input** — 115 volts plus or minus 15 volts, 60 cycles.
2. **Power Output** — Suitable for chart recorder or servo system feed. Output voltage is approximately plus or minus 15 volts for full scale range. It is a linear DC voltage.
3. **Output Impedance** — Approximately 600 ohms.
4. **Sensitivity Selection** — Three position switch with standard ratio 1:2.5:10. Other ratios available to special order.
5. **Damping** — Electronic with 0.1-2.0 seconds damping constants. Selected by two position switch.
6. **Scale** — Graduated to read directly in angular units.
7. **Connection to Sensing Unit** — Power amplifier is connected to sensing unit by 10 feet of electrical cable. Standard length of connection between amplifier and portable indicator is 50 feet. This length can be increased to 2500 feet on special order.

* • Electronic angle measuring and controlling instruments • Angular divisions on glass and metal accurate to better than one second of arc • Linear divisions on glass and metal accurate up to one part in 200,000 • Telescopic systems of all types • Special targets and reticules • Ultra-precise mechanical components.

1632

KEUFFEL & ESSER CO. Hoboken, New Jersey

CIRCLE 34 ON INQUIRY CARD

TABLE IV.

SUMMARY OF PRESSURE PICKUP CHARACTERISTICS

1. Manufacturer	BJ Electronics	BJ Electronics	Bourns Laboratories	Bourns Laboratories	Bourns Laboratories
2. Model No.	GP-15D	DP-7	717	304	409
3. Type	Gage	Differential	Absolute	Gage	Absolute
4. Pressure (psi)	0-10 to 0-6000	0-0.15 to 0-50	0-400 to 0-5000	0-100 to 0-5000	0-2 to 0-100
5. Pickoff	Magnetic	Magnetic	Resistance	Resistance	Resistance
6. Sensitive Element	Diaphragm	Diaphragm	Bourdon Tube	Bourdon Tube	Capsule
7. Linearity (±%)	1	1	0.8	1	0.6
8. Remarks	3 kc standard excitation, hi-shock, vibration resistant, natural frequency 3300 cps		Extreme vibration and shock. "Linearity" here means "static error band"	Linkage for multiplying motion	Linkage for multiplying motion
1. Manufacturer	Compu-tran, I R C	Compu-tran, I R C	Compu-tran, I R C	Consolidated Electrodynamics	Consolidated Electrodynamics
2. Model No.	70-2104	70-2002	70-2204	4-380	4-381
3. Type	Gage	Gage	Gage	Absolute, Differential	Differential, Gage, Absolute
4. Pressure (psi)	0-6	0-60	0-3000	0-7 to 0-100	600-1500, 600-5000
5. Pickoff	Resistance	Resistance	Resistance	Resistance	Resistance
6. Sensitive Element	Capsule	Bourdon Tube	Bourdon Tube	Capsule	Bourdon Tube
7. Linearity (±%)	1.5	1	1.5	1	1
8. Remarks	"Linearity" includes total error band	"Linearity" includes total error band	"Linearity" includes total error band	Missiles, miniature, hi-vibration	Hi-shock, missiles
1. Manufacturer	Giannini	Giannini	Haydon Switch, Inc.	Massa Div., Cohu Electronics, Inc.	Massa Div., Cohu Electronics, Inc.
2. Model No.	45154	451212	1500 Series	M-50	M-65
3. Type	Absolute, Differential, Gage	Absolute, Differential, Gage	Absolute, Differential, Gage	Absolute, Differential, Gage	Absolute, Differential, Gage
4. Pressure (psi)	0-10 to 0-50	0-10 to 0-100	8 Sensing modules cover from 0.5 to 4000	0-5 to 0-2000	0-2000 to 0-6000
5. Pickoff	Resistance	Resistance	Optional modules: Resist., Magnetic, Switch	Magnetic	Magnetic
6. Sensitive Element	Capsule	Capsule	Diaphragm or Piston	Diaphragm	Diaphragm
7. Linearity (±%)	1.2	0.8		0.25	0.25
8. Remarks	Miniature, hi-vibration, hermetic seal available	Hi-resolution and repeatability	Interchangeable modules, external sensitivity adjustment	1 kc min. exc. frequency	1 kc min. exc. frequency
1. Manufacturer	Pace Engineering Co.	Rahm Instruments	Rahm Instruments	Servonic Instruments	Servonic Instruments
2. Model No.	P21	134	143	H	D
3. Type	Gage, Differential, Absolute	Absolute, Differential, Gage	Gage	Absolute, Differential, Gage	Absolute, Differential Gage
4. Pressure (psi)	0-1 to 0-1000	0-15 to 0-300	0-100 to 0-5000	0-1000 to 0-10,000	0-100 to 0-1000
5. Pickoff	Magnetic	Resistance	Resistance	Resistance	Resistance
6. Sensitive Element	Diaphragm	Capsule	Bourdon Tube	Bourdon Tube	Bourdon Tube
7. Linearity (±%)	0.5	0.5 to 1	1	0.5	1
8. Remarks	Miniature	Miniature, infinite resolution pot	Available with infinite resolution output pot	Corrosive liquids, hi-pressure	Corrosive fluids, medium pressure

TABLE IV. Cont. SUMMARY OF PRESSURE PICKUP CHARACTERISTICS

1.	Bourns Laboratories	Bourns Laboratories	Colvin Laboratories	Colvin Laboratories	Colvin Laboratories	Compu-tran, IRC
2.	509	515	411	438	4416	70-2101
3.	Differential	Differential	Absolute, Differential, Gage	Gage	Absolute, Differential	Gage
4.	0-2 to 0-100	0-2 to 0-50	0-0.5 to 0-100	0-100	0-5 to 0-200	0-15
5.	Resistance	Resistance	Resistance	Resistance	Resistance	Resistance
6.	Capsule	Capsule	Capsule	Diaphragm		Capsule
7.	0.6	0.6	0.7 to 2	1	1	0.75
8.	Linkage for multiplying motion	Linkage for multiplying motion. To 450° F	Pressure range depends on type		Air or non-corrosive gas, Hi-G series	"Linearity" includes total error band

1.	Crescent Engineering & Research Co.	Fairchild Controls, Inc.	Fairchild Controls, Inc.	Fairchild Controls, Inc.	Fairchild Controls, Inc.	Fairchild Controls, Inc.
2.	PDI-2	TP-100	TPH-175	TP-201	TP-200	TP-300
3.	Differential, Gage	Absolute, Differential, Gage	Absolute, Gage	Differential	Absolute, Differential, Gage	Absolute, Differential, Gage
4.	0-1 to 0-100	0-5 to 0-350	0-100 to 0-10,000	0-5 to 0-100	0-5 to 0-100	0-5 to 0-100
5.	Magnetic	Resistance	Resistance	Resistance	Resistance	Resistance
6.	Diaphragm	Capsule	Bourdon Tube	Capsule	Capsule	Capsule
7.	2	1	1	1	1	0.75
8.		Hi-shock, vibration, acceleration	±0.5% linearity possible	Hi-line pressure, ±0.5% linearity possible	Temperature-compensated capsule	±0.5% linearity possible

1.	Norwood Controls	Norwood Controls	Pace Engineering Co.	Pace Engineering Co.	Pace Engineering Co.	Pace Engineering Co.
2.	501	1601	PI	P2G	P3D	P7D
3.	Absolute, Gage	Differential	Differential, Gage	Gage	Differential	Differential
4.	0-10 to 0-5000	0-1 (approx.) to 0-50	0-0.25 to 0-100	0-1000 to 0-10,000	0-0.1 to 0-2500	0-0.1 to 0-100
5.	Magnetic	Magnetic	Magnetic	Magnetic	Magnetic	Magnetic
6.	Bourdon Tube	Bellows	Diaphragm	Diaphragm	Diaphragm	Diaphragm
7.	0.5	1	1	0.5	0.5	1
8.	Complete readout access available	Complete readout access available	Natural frequency >3000 cps	Hi-pressure	Low differential pressure at high line pressure	Low differential pressure at high line pressure

1.	Servonic Instruments	Trans-Sonics, Inc.	Trans-Sonics, Inc.	Ultradyne, Inc.	Ultradyne, Inc.	Ultradyne, Inc.
2.	L	77 Series	78 Series	S-40	S-60	S-90
3.	Absolute, Differential, Gage	Absolute	Absolute	Absolute, Differential, Gage	Absolute, Differential, Gage	
4.	0-15 to 0-150	0-200 to 0-3500	0-15 to 0-50	0-0.1 to 0-5	0-5 to 0-5000	
5.	Resistance	Resistance	Resistance	Magnetic	Magnetic	
6.	Aneroid	Bourdon Tube	Bellows	Diaphragm	Diaphragm	
7.	0.5	±1	±1	1	1	
8.	Corrosive fluids, lo-pressure	Stainless steel for severe environments in missiles	Miniature, light weight, for severe environments in missiles	Lo-pressure	Miniature, for FM sub-carrier oscillation	

Similar to S-60 except temperature compensation is −65° F to +230° F

Transducers Cont'd.

POTENTIOMETER PICK-OFFS

Most pot manufacturers make a variety of low-torque pots or sector pots as "specials" for transducer applications. We do not include a buyers' guide on these special units. (See Buyers' Guide to Pot Manufacturers in 1958.) Nor do we include manufacturers' performance data on these units, since the requirements of the industry are so diverse.

"PICK-UPS"

Accelerometer and Pressure Pick-ups. Tables III and IV list manufacturers' data on typical accelerometers and pressure transducers. This information is presented to indicate the ranges of characteristics available in standard units.

Linear Motion Potentiometers. Linear motion potentiometers, widely used as displacement transducers, may be regarded as developed versions of the commoner rotary types. Their accuracy and resolution depend essentially upon the length of the resistance element.

A wide range of strokes is available. In the selection of a linear motion potentiometer, consider the alignment of the slider actuating rod, play and wear in the bearing, maximum slide speed and life, as well as the usual potentiometer selection factors (see Components Digest 2, Dec. 1958 Issue).

Although most potentiometer manufacturers may include some linear motion potentiometers in their line, the manufacturers listed in the Buyers' Guide place somewhat more emphasis on these items.

Buyers' Guide for Pick-offs and Transducers

INDUCTION POTENTIOMETERS

AMERICAN ELECTRONICS INC., 655 W.Washington Blvd., L. A., Cal.
CLIFTON PRECISION PRODS., Maple at Bdwy., Clifton Heights, Pa.
INDUCTION MTRS. CORP., 6058 Walker Ave., Maywood, Cal.
KEARFOTT CO., INC., 1500 Main Ave., Clifton, N. J.
MUIRHEAD INSTRUMENTS, INC., 677 Fifth Ave., New York, N.Y.

SYNCHROS

AMERICAN ELECTRONICS, INC., 655 W.Washington Blvd., L. A., Cal.
BENDIX AVIATION Montrose Div., South Montrose, Pa.
CLIFTON PRECISION PRODS., Maple at Bdwy., Clifton Heights, Pa.
DAYSTROM TRANSICOIL, Worcester, Montgomery City, Pa.
ECLIPSE PIONEER Div. of Bendix, Rt. 46, Teterboro, N. J.
T. A. EDISON IND. Instr. Div., 68 Lakeside Ave., W. Orange, N. J.
FORD INSTR. CO. Div. Sperry Rand, 31-10 Thomson Ave. L. I. City, N. Y.
GENERAL ELECTRIC Apparatus Sales, 1 River Rd., Schenectady, N. Y.
HELIPOT CORP. Div. of Beckman Instrument, Newport Beach, Cal.
INDUCTION MTRS. CORP., 6058 Walker Ave., Maywood, Cal.
KEARFOTT CO., INC., 1500 Main Ave., Clifton, N. J.
LEAR, INC., 110 Ionia Ave., NW, Grand Rapids, Mich.
MINN.-HONEYWELL Doelcam Div., Soldiers Field Rd., Boston, Mass.
MUIRHEAD INSTRUMENTS INC., 677 Fifth Ave., New York, N. Y.
NORDEN-KETAY Prec. Components Div., Commack, L. I., N. Y.
JOHN OSTER MFG. CO Avionics Div., 1 N. Main St., Racine. Wis.
SERVOMECHANISMS INC. Mechatrol Div., Prospect Ave., Westbury, N. Y.

RESOLVERS

AMERICAN ELECTRONICS, INC., 655 W.Washington Blvd., L. A., Cal.
BENDIX AVIATION Montrose Div., South Montrose, Pa.
CLIFTON PRECISION PRODS., Maple at Bdwy., Clifton Heights, Pa.
DIEHL MFG. CO., 1129 Finderne Ave., Somerville, N. J.
ECLIPSE PIONEER Div. of Bendix Aviation, Route 46, Teterboro, N. J.
FORD INSTR. CO. Div. Sperry Rand, 31-10 Thomson Ave., L. I. City, N. Y.
HELIPOT CORP. Div. of Beckman Instrument, Newport Beach, Cal.
INDUCTION MTRS., CORP., 6058 Walker Ave., Maywood, Cal.
KEARFOTT CO., INC., 1500 Main Ave., Clifton, N. J.
LEAR, INC., 110 Ionia Ave., NW, Grand Rapids, Mich.
MUIRHEAD INSTRUMENTS INC., 677 Fifth Ave., New York, N. Y.
NORDEN-KETAY Prec. Components Div., Commack, L. I., N. Y.
JOHN OSTER MFG. CO. Avionics Div., 1 N. Main St., Racine, Wis.
REEVES INSTR. CO., Roosevelt Field, Garden City, N. Y.

DIFFERENTIAL TRANSFORMERS

AUTOMATIC TIMING & CONTROLS, INC. King of Prussia, Pa.
G. L. COLLINS CORP., 2820 E. Hullett St., Long Beach, Cal.
COMPUTER COMPONENTS Div. IRC, 401 N. Broad St., Phila., Pa.
DAYTRONIC CORP., 216 S. Main St., Dayton, Ohio
DYNAMIC MEASUREMENTS CO., 301 Old York Rd., Jenkintown, Pa.
MINATRON CORP., 14 Cliveden Place, Belle Mead, N. J.
SCHAEVITZ ENGINEERING, P. O. Box 505, Camden, N. J.
VINSON MFG. CO., 8044 Woodley Avenue, Van Nuys, Cal.

MICROSYNS

DETROIT CONTROLS, 100 Morse St., Norwood, Mass.
MINN.-HONEYWELL Doelcam Div., Soldiers Field Rd., Boston, Mass.
STERLING PREC. CORP., 34-17 Lawrence St., Flushing, N. Y.
TOLEDO SCALE CO., 5225 Telegraph Road, Toledo, Ohio

MAGNESYNS

BENDIX AVIATION Friez Inst. Div., Taylor Ave., Baltimore, Md.

SYNCHROTELS

KOLLSMAN INSTR. CORP., 80-08 45th Ave., Elmhurst, N. Y.

INDUCTOSYNS

FARRAND OPTICAL CO., Bronx Blvd. at 238th St., N. Y., N. Y.

ACCELEROMETERS (using inductive or resistive pick-offs)

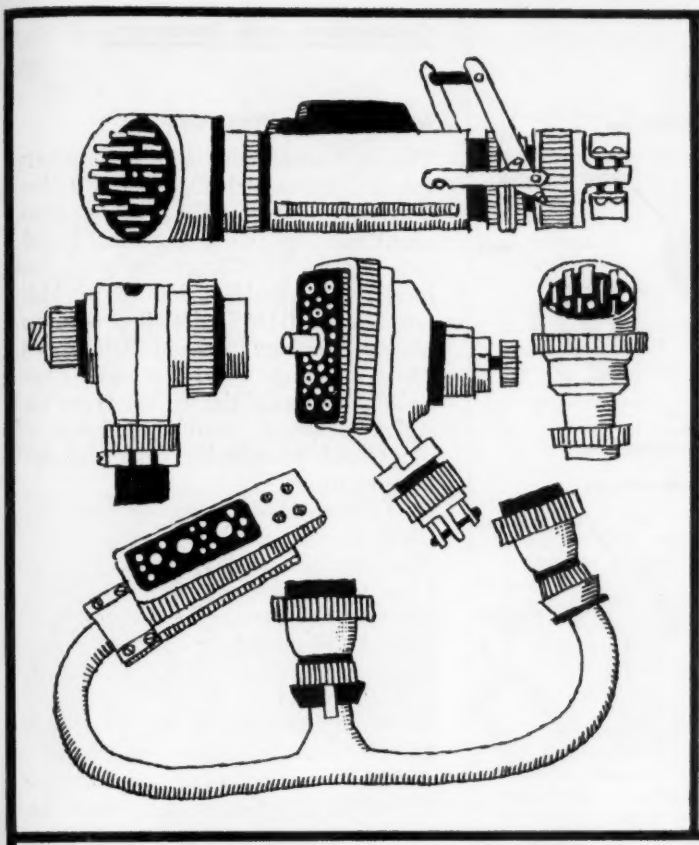
BOURNS LABS, P. O. Box 2112, Riverside, Cal.
CONSOLIDATED ELECTRODYNAMICS CORP., Pasadena, Cal.
FAIRCHILD CONTROLS CORP. Comp. Div., Hicksville, N. Y.
GIANNINI & CO., 918 E. Green St., Pasadena, Cal.
HUMPHREY INC., 2805 Canon St., San Diego, Cal.
PACE ENGINEERING CO., 6914 Beck Ave., N. Hollywood, Cal.

PRESSURE TRANSDUCERS (using inductive or resistive pick-offs)

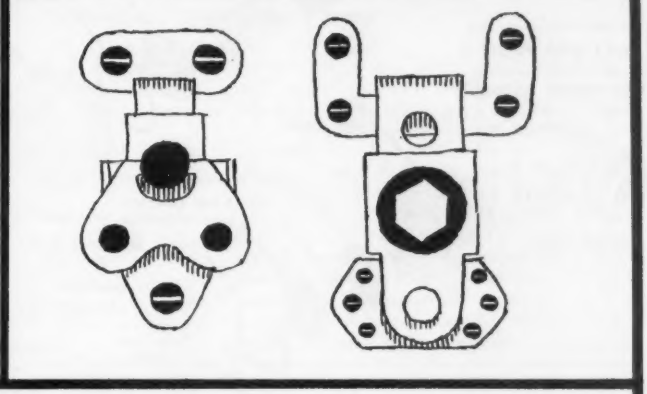
BJ ELECTRONICS Borg Warner Corp., Santa Ana, Cal.
BOURNS LABS, P. O. Box 2112, Riverside, Cal.
COLVIN LABORATORIES, 364 Glenwood Ave., E. Orange, N. J.
COMPUTER COMPONENTS Div. IRC, 401 N. Broad St., Phila., Pa.
CONSOLIDATED ELECTRODYNAMICS CORP., Pasadena, Cal.
CRESCENT ENGINEERING & RES. CO., 5440 N. Peck Rd., El Monte, Cal.
FAIRCHILD CONTROLS CORP. Comp. Div., Hicksville, N. Y.
GIANNINI & CO., 918 E. Green St., Pasadena, Cal.
HAYDON SWITCH, INC., Waterbury, Conn.
KINTEL Div. Cohu Electr., Kearny Villa Rd., San Diego, Cal.
MASSA LABS Div. Cohu Electr., Fottler Rd., Hingham, Mass.
NORWOOD CONTROLS, 934 Washington St., Norwood, Mass.
PACE ENGINEERING CO., 6914 Beck Ave., N. Hollywood, Cal.
RAHM INSTRUMENTS, 65 Rushmore St., Westbury, N. Y.
SERVONIC INSTRUMENT CO., 640 Terminal Way, Costa Mesa, Cal.
TRANS-SONICS, P. O. Box 328, Lexington, Mass.
ULTRADYNE, INC., P. O. Box 8007, Albuquerque, N. M.
WIANCKO ENGINEERING CO., 255 N. Halstead Ave., Pasadena, Cal.

RECTILINEAR POTENTIOMETERS

AERO ELECTRONICS CORP., 6053½ Whittier Blvd., L. A., Cal.
BOURNS LABS, P. O. Box, 2112, Riverside, Cal.
CLAROSTAT MFG. CO., E. Washington St., Dover, N. H.
COLVIN LABORATORIES, 364 Glenwood Ave., E. Orange, N. J.
COMPUTER INSTR. CORP., 92 Madison Ave., Hempstead, N. Y.
DEJUR-AMSCO CORP., 45-01 Northern Blvd., L. I. City, N. Y.
ELECTROMATH CORP., 42-14 Greenpoint Ave., L. I. City, N. Y.
ELECTRO-SERV CO., 480 Johnson Ave., Brooklyn, N. Y.
FAIRCHILD CONTROLS CORP. Comp. Div., Hicksville, N. Y.
GENERAL CONTROLS CO., 801 Allen Ave., Glendale, Cal.
MARKITE CORP., 153 Waverly Place, N. Y., N. Y.
MINCO PRODUCTS, 740 Washington Ave., No., Minn., Minn.
PRECISION LINE, INC., 63 Main St., Maynard, Mass.
TECHNOLOGY INSTRUMENT CORP., 551 Main St., Acton, Mass.



COMPONENTS 6 DIGEST



CONNECTORS and FASTENERS

This Components Digest is devoted to two items of vital importance in the design of reliable and useful electromechanical equipment: *connectors* and *fasteners*. Emphasis on both these items is increasing sharply, primarily as a consequence of increasing complexity of military equipment and the severe environments to which this equipment is subjected. Modular construction with its well known advantages relies heavily on reliable connectors for interconnecting modules, and on fastening devices that operate quickly and reliably under severe vibration, shock, and in corrosive atmospheres.

Because of their importance to electromechanical design engineers, we will cover connectors and fasteners in depth and on a continuing basis in the Components Digest series. This introductory presentation is limited to:

- Connectors covered by military specifications or closely related units for making connections between equipments, but not including RF or printed circuit types;
- Quick operating fasteners.

CONNECTORS

Because of the quantities in which connectors are used, and the rugged handling and severe environments to which they are subjected, their mechanical and electrical reliability is extremely important. In servicing mal-functioning equipment, new sub-assembly packages are plugged-in as quickly as possible to restore satisfactory operation and the connector is usually assumed satisfactory. Such an assumption leads to extreme confusion when the connector is faulty. The connector shell is apt to be structurally stronger than internal parts with the result that a faulty connector is not easily identified. As with most other electromechanical apparatus, suitable operation is achieved by proper selection, careful installation, and operation under conservative conditions.

Selection Factors

Table I lists some of the factors of importance in choosing and using electrical connectors. It is designed as a check list to be scanned before final specification of a connector. Some of the items are discussed more fully in Table III. In spite of the tremendous variety of commercially available connectors, a large proportion of connector business is for "specials," making awareness of design and selection factors particularly important.

General Construction

Depending upon application, the variety of electrical connectors is enormous. Nevertheless, they have many construction features and configurations in common, typical examples of which are shown in Figs 1 through 4. Table II presents some definitions of connector terms as suggested by Cannon Electric. Figure 5 illustrates the various coupling techniques used in connector designs.

Design Considerations

Appreciation of design factors is helpful in selecting and applying electrical connectors. Principal among these are factors relating to the capacity and spacing of contacts to meet current and voltage requirements, particularly at high altitudes and under conditions of high humidity. The nature of the seal is important in determining high altitude performance. Extreme environments also dictate use of certain materials and configurations. Table III lists important design factors and discusses them in detail.

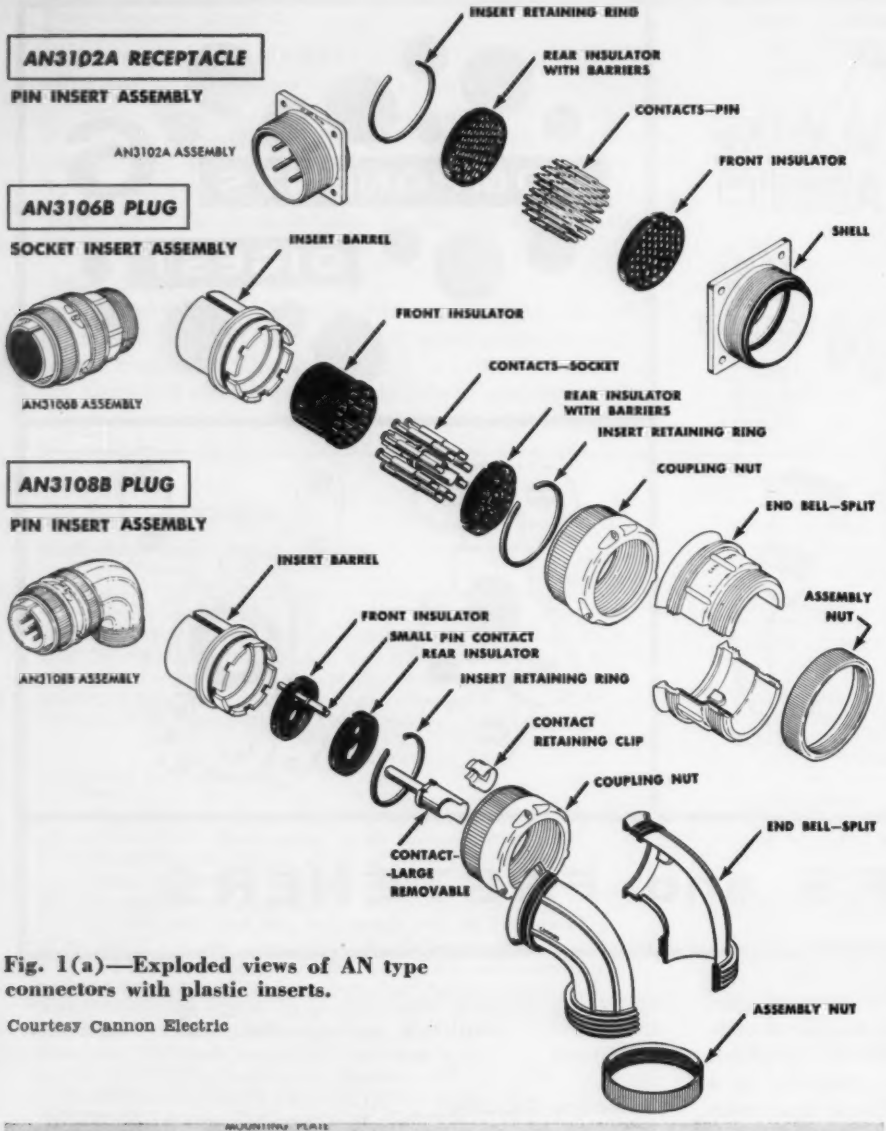


Fig. 1(a)—Exploded views of AN type connectors with plastic inserts.

Courtesy Cannon Electric

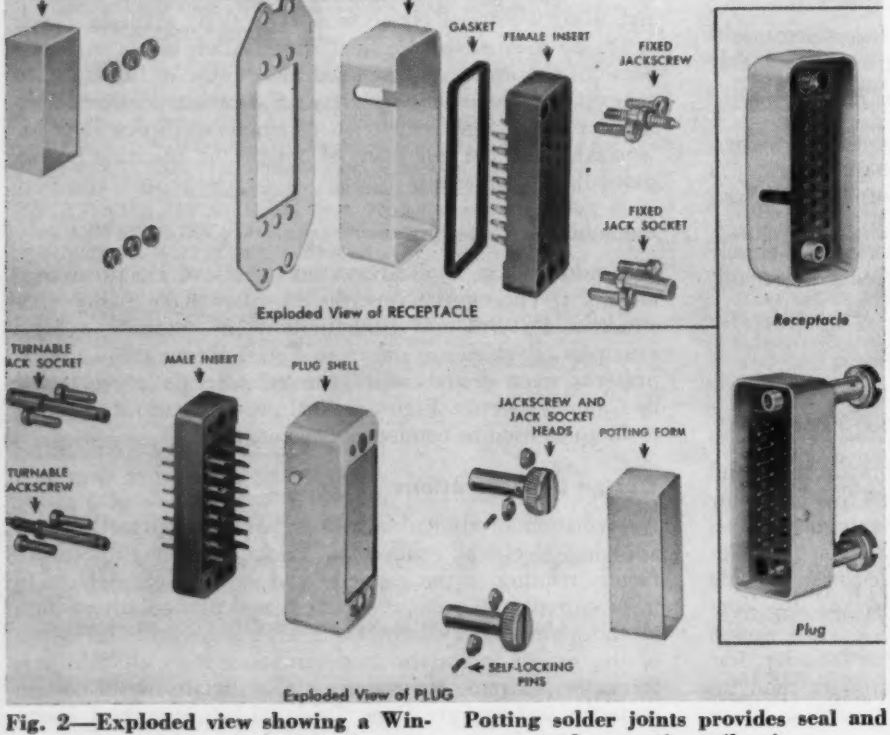


Fig. 2—Exploded view showing a Winchester miniature rectangular connector. Potting solder joints provides seal and supports them against vibration.

Connectors and Fasteners

Military Specifications

The most commonly referenced military specification is MIL-C-5015C, for electrical connectors. This specification, coordinated by the Aeronautical Standards Group (ASG), covers plug and receptacle assemblies defined by Military Standard (MS) drawings with applicable numbers in the MS3100 series. These drawings cover the basic physical dimensions of the various types and styles, assuring interchangeability of plugs and receptacles from different manufacturers.

Five classes of shells are covered:

Class A—solid shell
Class B—Split shell
Class C—Pressurized
Class E—Environment resisting
Class K—Fireproof

Supplementing MIL-C-5015C and the Military Standard drawings, are AND drawings (Army-Navy drawings) with 10,000 series numbers, which show standard arrangements of contacts. QPL-5015 is a Qualified Products List tabulating commercially available connector products qualified under MIL-C-5015C. Specification requirements are concisely reviewed in Table IV.

A large number of connectors used within and external to electronic equipment are covered by Air Force Specification MIL-C-8384 (USAF). This specification describes small hex-shaped connectors widely used to connect sub-assemblies within equipment that may be removed as units for servicing.

MIL-C-25955 (USAF), prepared at Wright Air Development Center, establishes military requirements for a miniature MS-type connector. Other military specifications include:

MIL-C-26500, Miniature connectors
MIL-C-26518, Rack and panel connectors
MIL-C26636, Connector contacts, removable crimp type
MIL-C-21097
MIL-C-26482

In addition to these specifications (and similar others) there are the commonly referenced environmental specifications, MIL-E-5272 and MIL-STD-202 (see Components Digest 4, covering environmental specifications). Non-military related specifications are issued by the SAE, AISI, ASA and ASTM.

Recently MIL-C-5015 has been revised by the Dept. of Defense as the "D" revision. The most important changes are in the classes of MS connectors, the object of which was to cut down the variety to be carried in inventory. Most Class A and Class B connectors and all Class C and Class E connectors are in-

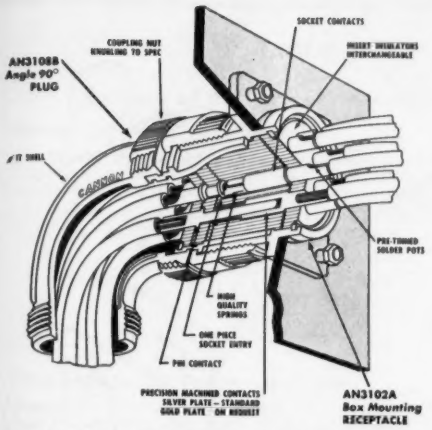


Fig. 1 (b)—Mated plug and receptacle.

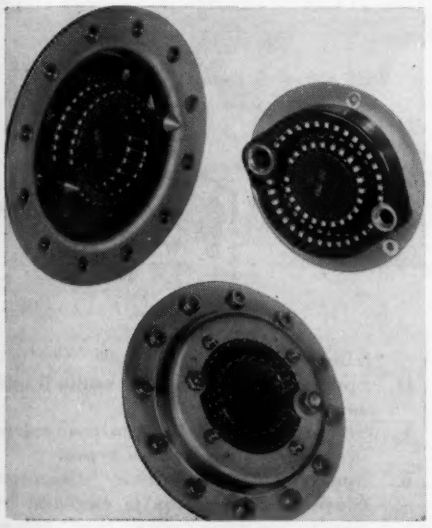


Fig. 3—Amphenol-Borg circular connector, rack and panel style, used in vapor-sealed radio equipment container for replaceable plug-in unit. The gold plated ribbon type contacts operate on the wedge principle, providing high individual contact pressure combined with low insertion and extraction force requirements, as well as positive contact under vibration and good wiping action. Note the barriers between adjacent contacts, which increase the length of surface leakage paths.

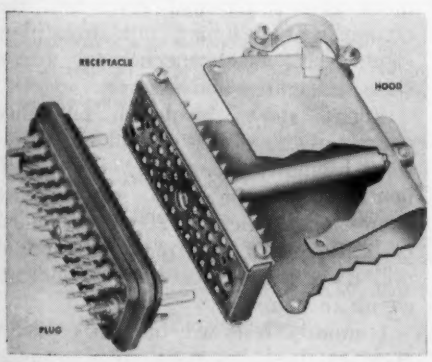


Fig. 4—Pressurized connector by Continental for guided missile application. Center screwlock permits fast engaging and disengaging of connector. The 40 contacts are spring loaded for easy release. The clamping device on the hood is a cable clamp, which relieves wire stresses at the solder joints.

TABLE I
Connector Selection Factors

Specification approval, contractual requirements.
Voltage rating, with allowance for inductive surges.
Current rating establishes size of contacts.
Contact spacing, determined by voltage requirements.
Number of contacts.
Type of contacts, technique for wire attachment.
Dimensional requirements—mounting space, shape, room for disengagement.
Coupling method—availability of space, ease and frequency of decoupling, vibration requirements, threaded couplings, bayonet type, latchlock, quick disconnect.
Shielding—solder shielding to connector shell.
Thermocouple contacts, to match materials of thermocouple.
Polarization, to avoid incorrect engagement.
Type of sealing—pressure seal, hermetic seal.
Force for coupling and decoupling.
Environmental conditions—temperature, altitude, humidity, corrosive atmospheres, radiation.
Special conditions of use.

TABLE II
Common Connector Terms

Plug—Specifically, the half of a connector that is normally movable; generally, either a complete connector or the plug or receptacle individually.
Receptacle—The stationary half of a connector, usually mounted on a wall, chassis or equipment box.
Endbell/Backshell—Metal fitting on rear of a plug or receptacle to which a cable clamp or conduit adapter can be threaded. Provides for proper spacing of cable clamp relative to the solder joints.
Stowage Receptacle—Also called a dummy receptacle. Consists of simply a receptacle shell less insert and contacts. Used to hold a plug (of the same shell size) when it is not in use. Especially useful in bench fabrication of wiring harnesses.
Reverse—Type Coupling Nut—A coupling nut which has an external thread rather than internal. Reverse-type receptacles, with threaded portion inside the skirt, obviously must be used with reverse coupling nuts. Often used in applications in which an exposed receptacle thread could be damaged.
Grommet—Resilient member used in connectors to seal points where wires or cables enter the assembly. Often used to provide a moisture-proof seal.
Ferrule—A short tube or bushing used as a connector accessory, often used to adapt conduit to the connector shell while maintaining a complete shield over the conducting wires. Has application in compression of grommets.
Collet—A small collar or band used to secure parts together or hold in place.
Back Mounting—When a receptacle flange is mounted "behind" a panel it is said to be back-mounted. Wiring assemblies which are made up on the bench away from the job are usually back-mounted.
Potting—A sealing process in which a compound, usually synthetic rubber, is spread between and around the wires at the rear of a connector. The compound dries to a hard rubber-like solid.
Interfacial Seal—An expression used to describe the condition when, in a mated pair of connectors, the plug insert presses against the receptacle insert with a force sufficient to seal off the insert faces. Applicable only to resilient insert materials.
Floating Eyelet—Used often in rack-and-panel designs to permit the connector to "float" free of the unit on which it is mounted. Makes for easier mating when parts to be mated are slightly misaligned. Eyelet is a metal bushing which is allowed to move freely in a usual mounting hole.

TABLE III
Some Connector Design Factors

Voltage rating—Dirt, humidity and reduced atmospheric pressure produce appreciable reduction in flashover ratings. Direct relation between voltage rating and contact spacing. Corona in rarified atmospheres reduces effective distance between contacts. Flashover may occur between contacts, or from contacts to shell. Insulation barriers are sometimes incorporated on insert to increase surface distance between contacts.
Current rating—Depends principally on resistance of the contact to flow of current. Resistance includes conductor portion, depending upon contact size and resistivity of material, and quality of contact which depends upon surface finish, contact pressure, and area in contact.
Coupling method—Coupling method determines ease with which circuits may be connected and disconnected, and reliability of mating during shock and vibration. Availability of space is important since there must be enough room to manually apply the direct pull necessary to separate the two halves of the connector. Figure 5 shows a variety of common coupling techniques for electrical connectors.
Separation force—Depends principally on the number and nature of the contacts. A compromise is necessary between the need for firm contact with heavy surface pressure, and the necessity for easy manipulating of the connector. Snap in contacts require high initial force to dislodge. Tapered contacts, or wedged ribbon contacts provide good connections with reasonable insertion and separation forces. In large connectors with a great many contacts, mechanical devices are incorporated to assist locking and withdrawal.
Connections—Crimping or soldering connecting is employed where a large number of connections are required in a small area. Many manufacturers feel that solderless connections are more reliable, not only with respect to the quality of the joint, but also in the avoidance of heating which may damage adjacent insulation. Solderless connecting is fast, and with suitable tools, connections are readily changed in the field. In high power connectors, soldering is often performed on the individual connector pins, to avoid heat damage. Solderless connections are obviously superior for the high temperature region extending from the softening point of soft solder to above 1000F. Soldered connections must employ high temperature solder, or some brazing operation.

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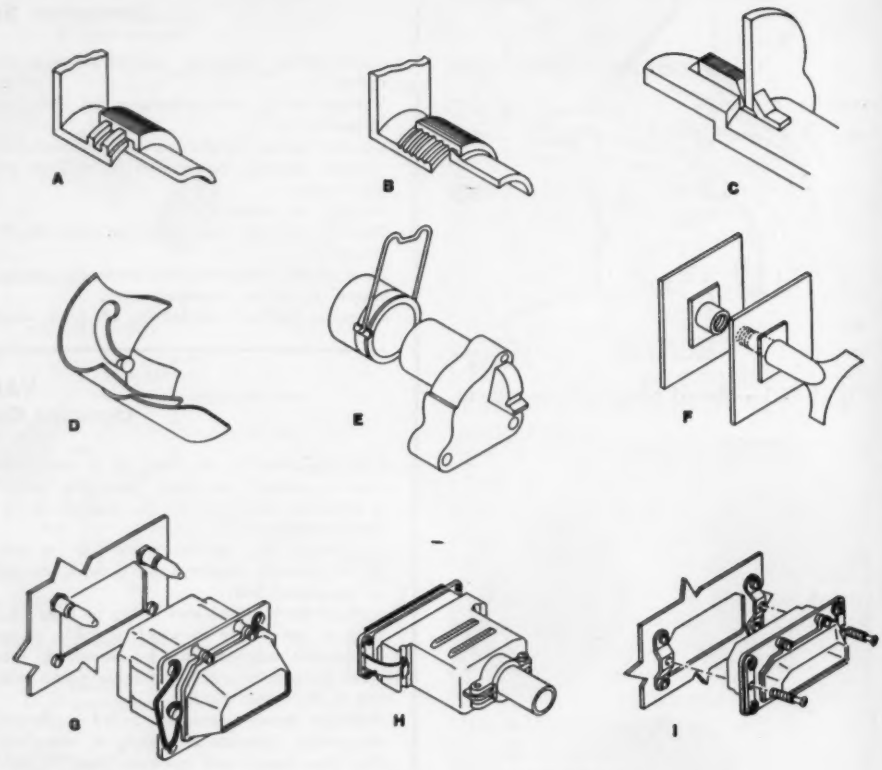


Fig. 5—Methods of coupling electrical connectors:
A Acme threaded coupling nut.
B Standard screw thread coupling nut.
C Spring loaded latch lock.
D Bayonet type coupling.
E Ball latch coupling.
F Center screw engaging mechanism.
G Spring lock which snaps into pins to lock connector together. These locks can also be used as a polarizing means.
H Spring clips which lock endbell and connector.
I Screw fastening for positive retention of rack and panel types.
K Spring loaded quick diconnect coupling. Connector is engaged by simply pushing plug over receptacle. Disengagement is by simply pulling back on coupling nut.

Courtesy Cannon Electric

activated. Class K connectors remain unchanged. Class C and E connectors are superseded by the new environment-resisting light-weight Class R. The older classes are still to be used on equipment already designed, and therefore all classes continue to be included in MIL-C-5015D since this specification is primarily a procurement document. The new classes should be used in new equipment design.

Environment

Components Digest 4 surveyed the general area of environmental testing. Wm. Peverill of Cannon Electric Co. has described the important environments that affect connector reliability; some of his material is abstracted below along with supplementary data.

HUMIDITY AND WATER

When relative humidity exceeds 80%, it becomes a major cause of electrical breakdown. A humid environment causes absorption and diffusion of water vapor on the surface of insulators. It may easily cause insulation resistance to drop below the megohm range, in which case high-potential failure can be expected.

Humidity may have a permanently degrading effect on both conductors and insulators, especially when accompanied by temperature fluctuations with periods of wetting and drying. Prolonged exposure to this environment causes physical distortion, decomposition, leaching out, breathing, electrolysis, electromechanical corrosion, and cracks and fissures.

Fig 6 shows insulation resistance characteristics under variable temperature humidity conditions for Continental Connector Corp. subminiature connectors, Series SM20 with molded bodies using an assortment of standard military approved materials as indicated on the curves.

Humidity tests are of two types: a constant humidity test to determine moisture absorption properties of insulation materials and to check the ability of sealed units to resist moisture penetration; and a temperature-cycled moisture resistance test to determine ability of materials to stand up under prolonged wet-and-dry cycling and to

TABLE IV

Review of Specification—Mil-C-5015C

PARAGRAPH 4.5.2 High Potential

Breakdown shall not show when voltage is applied for one minute between the two closest contacts, and between the shell and the contacts closest to the shell.

Service rating	Test voltage (rms) (60 cps)
Inst	1000
A	2000
D	2800
E	3500
B	4500
C	7000

PARAGRAPH 4.5.3 Temperature Cycling

Within 45 minutes after being subjected to 5 cycles of temperature changes for not less than 30 minutes at the maximum and minimum temperatures, the connectors shall meet the High Potential Test.

Sequence	
start at (high)	+185°F
reduce to (low)	— 67°F
return to	+ 68°F

PARAGRAPH 4.5.4 Contact Retention

After submission to temperature cycling test, individual contacts, as measured installed with other contacts in place, are to withstand the loads in either direction as shown below.

Contact size	Axial Load (minimum)
16	10 lb
12	15 lb
8	20 lb
4	20 lb
0	20 lb

PARAGRAPH 4.5.5 Humidity

Mated and wired connectors shall meet a potential test of 1½ times the following ac voltage for a period of 5 minutes after being exposed to a temperature of 160° ± 3.6°F and a relative humidity of 95 ± 3% for a period of 14 days.

Service rating	ac volts (rms)
Inst	200
A	500
D	900
E	1250
B	1750
C	3000

PARAGRAPH 4.5.6 Corrosion

Mated connectors shall meet a potential test of twice the ac voltage of Paragraph 4.5.5 and the resistance of contacts test after being subjected to 50 hours of salt spray.

PARAGRAPH 4.5.7 Resistance of Contacts

The resistance at 77° ± 5°F. of pin and socket contacts when assembled as in service is to be such that the potential drop at the specified test current will not exceed that shown below.

Contact size	Test Current (amperes)	Potential Drop (millivolts) (max)	After Corrosion Test Potential Drop (mv.)
16	20	21	30
12	35	20	30
8	60	12	25
4	110	10	20
0	200	10	20

PARAGRAPH 4.5.8 Insulation Resistance

At a temperature of 77° ± 5°F., insulation resistance as measured between contacts and between contacts and shell to be greater than 5,000 megohms.

PARAGRAPH 4.5.9 Force Required to Disengage AN3107 Plug

The axial load to separate an AN3107 plug shell only, from a mating receptacle to be 6 ± 2 lbs.

PARAGRAPH 4.5.10 Vibration: Method I

Wired and mated connectors shall not disengage, crack, break, or loosen, and there is to be no interruption of continuity of circuit contacts, when subjected to procedure 1 of specification MIL-E-5272. After test the connector to meet High Potenial Test and Physical Test.

PARAGRAPH 4.5.11 Physical Shock

The parts of the connector shall show no damage and the contacts shall meet the Resistance of Contacts Test after being subjected to a deceleration of 50 gravity units.

PARAGRAPH 4.5.12 Durability

After 500 cycles of insertion and withdrawal at a rate not exceeding 600 cycles per hour, the connector is to show no electrical or mechanical defects. Insert assemblies are then to undergo Corrosion Test, after which they are to meet potential drop values shown in last column of the table of paragraph 4.5.7.

PARAGRAPH 4.5.13 Immersion

Unmated connectors are to be immersed in the following fluids, one connector in each fluid, after which they are to withstand the following voltage for 5 minutes.
(a) Aviation hydraulic fluid.
(b) Aircraft lubricating oil.

Service rating	A-C volts (rms)
Inst	400
A	1,000
D	1,400
E	1,750
B	2,250
C	3,500

PARAGRAPH 4.5.14 Contact Engaging and Separating Forces

The average force required to engage or separate random picked pins and sockets, shall not exceed the average, and shall be within the range of maximum and minimum values below.

Contact Size	Average	Maximum	Minimum
16	2.1	3	¼
12	3.5	5	½
8	7	10	¾
4	10.5	15	1
0	14	20	2

PARAGRAPH 4.5.14.1 Resistance to Test Prod. Damage

Size 16 socket contacts are to meet the requirements of 4.5.14 after having test prod of nominal mating pin diameter inserted ⅛", ⅜", and ¼" depths as measured from the face of the insert, and a bending moment of 2 in. lbs. ± 10% is applied to the prod as the prod is rotated to 360°.

PARAGRAPH 4.5.15 Resistance to Arc

Using specific circuit and conditions, an insert material disc conforming to designation 2 of MIL-P-14 is to be tested in accordance with MIL-P-14. The resistance to arc of the disc per this test is to be a minimum of 115 seconds.

PARAGRAPH 4.5.16 Dielectric Strength

After an insert material disk is conditioned per E-48/50 + D-48/50 of MIL-P-14, the dielectric strength to be minimum of 100 volts per mil.

PARAGRAPH 4.5.17 Dimensional Stability

An insert material bar is conditioned for 96 hours at 25°C. and 50% relative humidity, and then measured to the nearest .001. The bar is then cycled for 48 hours at 125° ± 5°C. and 50% relative humidity, followed by 24 hours at 25° ± 5°C. and 50% relative humidity. After 10 cycles the bar is again measured and the percentage change in length as calculated below is not to exceed 7%.

$$\text{Dimensional change (\%)} = \frac{\text{initial length} - \text{final length}}{\text{initial length}} \times 100$$

PARAGRAPH 4.5.18 Air Leakage

After minimum exposure time to extreme temperatures of Temperature Cycling Test, AN3100 and AN3102 receptacles are to prevent leakage of more than 1 cubic inch of air per hour at a pressure differential of 30 psi.

PARAGRAPH 4.5.19 Fireproof

A mated AN-K plug and receptacle is to carry the D-C current indicated below for 5 minutes and prevent the passage of flame for 20 minutes while undergoing the following test: The connector is subjected to a 2,000°F flame as measured ¼ inch from the assembly, while it is vibrated continuously at 2,000 cpm with a total excursion of ¼ inch. During the sixth minute of the test 110/125 volts at 60 cps is applied between adjacent contacts, and contacts and shell without exceeding 2 amperes of line current.

Contact Size	Amperes
16	22
12	41
8	73
4	135
0	245

PARAGRAPH 4.5.20 Vibration, Method II

AN-E connectors are to be tested per procedure II of MIL-E-5272 as well as the requirement of paragraph 4.5.10 (Vibration, Method I.)

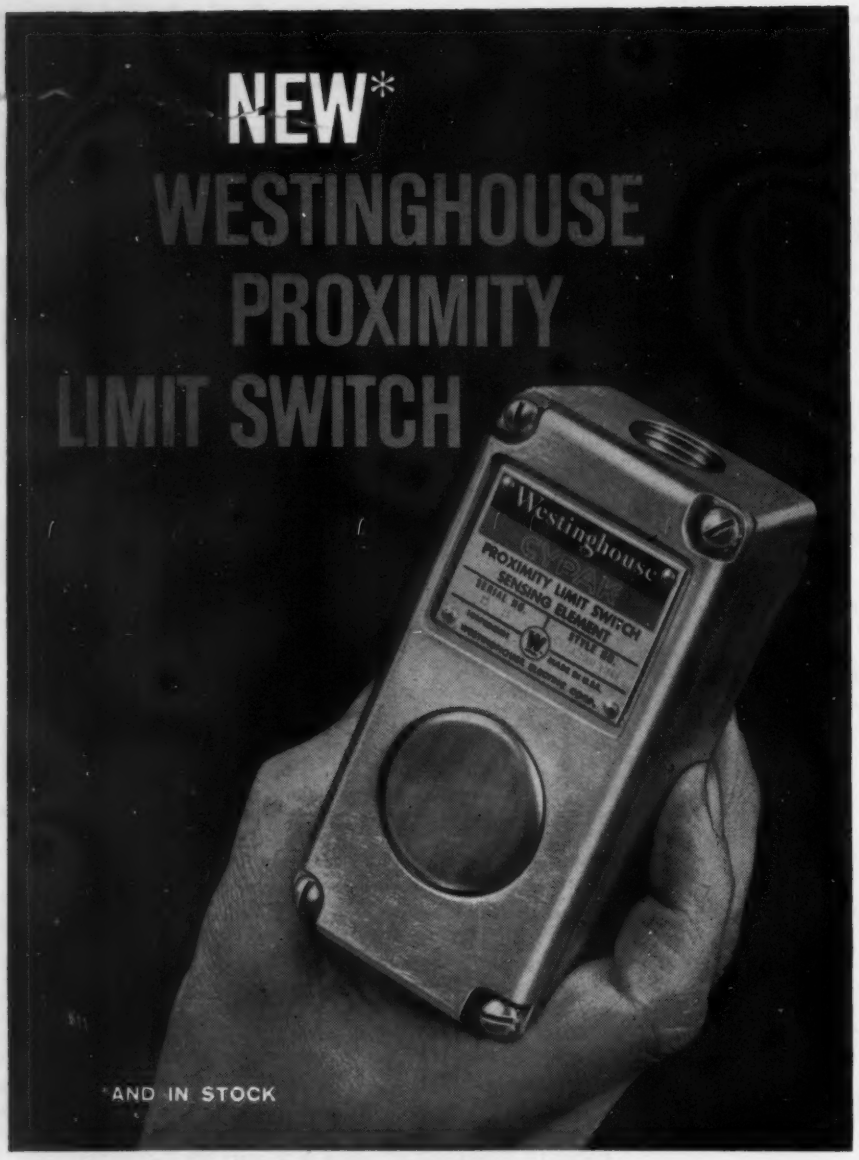
PARAGRAPH 4.5.21 Moisture Resistance

A mated AN-E plug and receptacle that is completely wired is subjected to the Temperature Cycling Test, and the Vibration, Method II Test. The connector is then placed in a test chamber for 20 days that varies the air temperature 5°C. once an hour, within the range of 22°C. and 28°C., causing heavy condensation to form hourly. At the beginning and once a day for the 20 days the insulation resistance between each contact and other contacts and shell is not to be less than 100 megohms as measured by 500-volt megger or megohm bridge.

PARAGRAPH 4.5.22 Insert Retention

AN-C and AN-E insert assemblies are to retain their normal location in connector shell for 5 seconds while withstanding axial load in either direction as shown below. The plug and receptacle to be conditioned prior to this test by undergoing the Temperature Cycling Test.

Connector Size	Gage Pressure (psi)
8 through 12	150
14 through 18	100
20 through 22	75
24 through 28	60
32 through 40	45



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Whenever exposure to rain, spray, or water immersion is anticipated, sealed units are used exclusively, sealing of electrical circuits and terminals is indicated.

Environment resisting connectors, AN-E, and recently, AN-R, are completely sealed against moisture by resilient grommets and inserts, and gasketed mating surfaces and sealing washers.

HEAT AND COLD

High temperature exposure causes permanent damage to most dielectric materials. Insulation resistance is lowered and moisture absorption is increased after exposure. In metals, high temperature accelerates oxidation, and causes plating to deteriorate. Fig 7 illustrates the deterioration of service life for a Bendix connector.

Extremely low temperatures, such as are encountered in arctic exposure and in missile liquid oxygen systems, may also cause cracks and delamination in insulators. Common temperature requirements cover −65°C to +250°C, but may extend to +540°C.

A temperature shock test is given to stimulate surface exposure to the sudden temperature changes that would be experienced when equipment is transferred to and from heated shelters in arctic areas, or subjected to the temperature extremes of a satellite environment. Temperature shock tends to produce cracks and delamination.

Another form of temperature shock is produced in the heat flux test. Here the sample is subjected to extremely rapid input of radiant heat to stimulate friction heating of an object entering the earth's atmosphere. The rapid surface heating and expansion that result may cause warping, flow, melting, or sublimation.

VIBRATION AND SHOCK

As the speed of aircraft and missiles has increased, the forces of vibration and shock have become increasingly severe. To adequately simulate this environment, tests must often include random and complex-wave vibration. Sine wave testing covers the range to 2000 cps, and up to 50 g's.

Shock forces to 50 g's usually occur as transient vibrations resulting from a shock pulse. Complimentary shock and acceleration tests are made to simulate such conditions as jet and rocket take-off. Related to shock is the condition of explosion—a combination of shock and pressure.

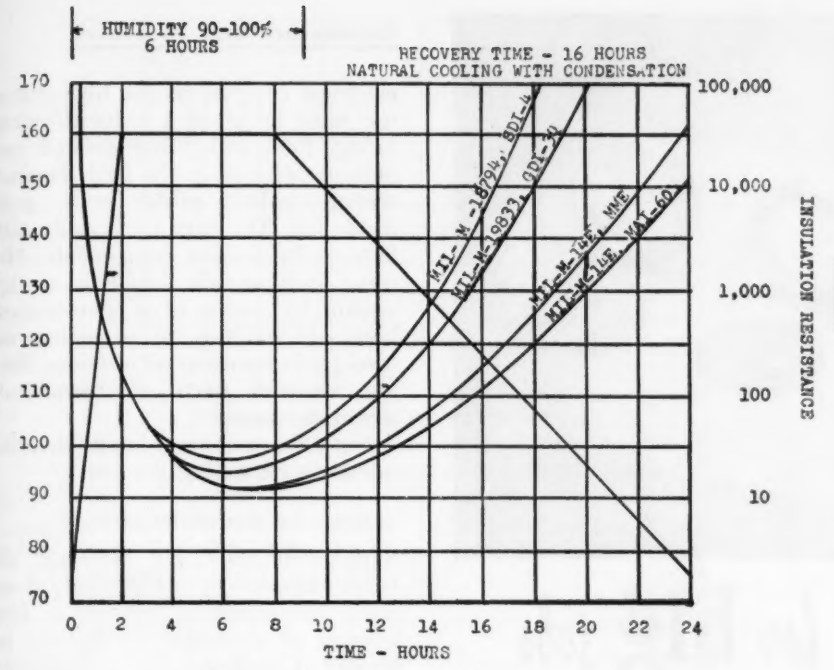

Fig. 6—Insulation resistance versus time, high temperature-humidity.

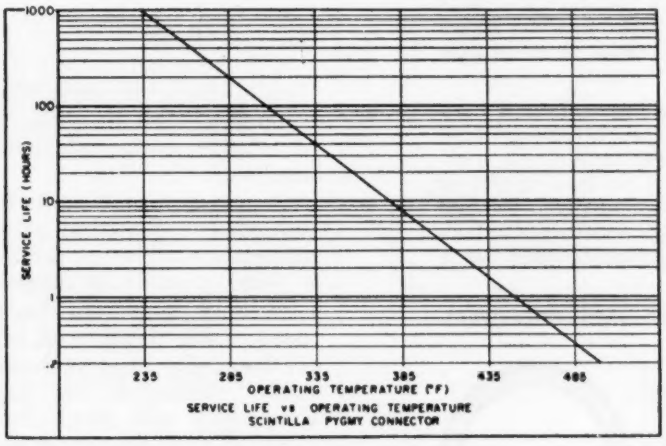

Fig. 7—Service life vs. temperature.

Vibration may crack the insert material of an electrical connector, break wires at the solder joints, or even cause the mating parts to separate. A rubber ring between insert and shell, or a resilient insert provides some degree of shock mounting. The quality of the solder joint is a major reliability factor. Comparison of solderless and soldered connectors is currently receiving high priority, constituting a major topic at the Electronic Industries Association (EIA) conference on Reliable Electrical Connections.

To prevent accidental disconnect as a result of vibration, an appropriate locking means must be selected. Selection factors depend upon the frequency of uncoupling, the severity of the vibration, the force required for coupling or uncoupling, and the importance of speed. While screw-type couplings employing safety wiring are most common, quick disconnect locks, latching devices, and many specialized mechanisms are available. Where hundreds of contacts may be involved, the forces required for engagement and disengagement may be large, and complex locking mechanisms employing cams and levers may be necessary.

Cable clamps are recommended where the bulk of the cable may be such as to subject the connector contacts to severe strains.

ALTITUDE

The reduced atmospheric pressure that accompanies an increase in altitude has the effect of lowering the insulation strength of air. The result is an increased tendency toward voltage flashover and corona effect as illustrated typically in Fig 8. Altitude requirements commonly extend to 110,000 ft.

A non-sealed component that has a voltage rating of 10,000 volts at sea level would flashover at about 1600 volts at 80,000 feet (assuming equal temperatures). As a result, non-sealed

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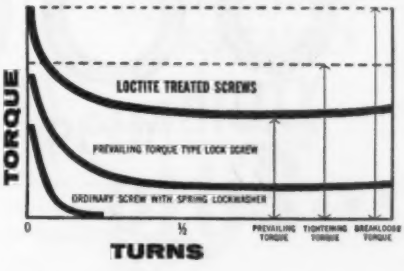
4. LOCTITE comes in different strengths which apply any required locking torque—ranging from a light drag suitable for adjustment screws to a locking force exceeding the torsional strength of the screw. Provides greater uniformity than mechanical staking.

LOCKING CHARACTERISTICS OF LOCTITE



LOCTITE is a thin liquid that hardens when confined between closely fitting metal parts. It forms a tough, heat and oil-resistant, bond that secures threaded parts better than any mechanical locking device. Write for literature and free sample.

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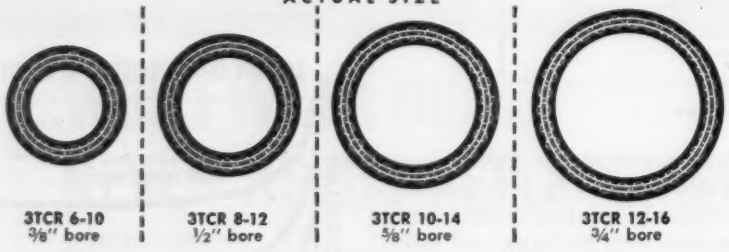
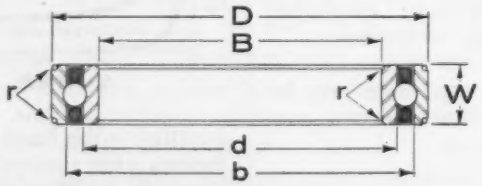
ACTUAL SIZE





*B bore ± .0002	*D o.d. + .0000 − .0004	W width + .0000 − .0050	†r radius	b outer land ± .001	d inner land ± .001	Balls no.	Balls size	‡L lbs.	§S lbs.
.3750	.6250	.15625	.010	.542	.457	16	1/16	77	110
.5000	.7500	.15625	.010	.672	.587	21	1/16	89	144
.6250	.8750	.15625	.010	.797	.712	24	1/16	94	165
.7500	1.0000	.15625	.010	.922	.8375	30	1/16	101	206

Dimensions are in inches. *Tolerances shown are for Precision Grade. Write for Ultra Precision Grade tolerances. †r is maximum fillet radius on shaft or housing that bearing will clear. ‡Radial load capacity at 500 rpm and 2500 hours average life. §Static non-Brinell load capacity.

split ballbearing
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CIRCLE 38 ON INQUIRY CARD

electrical components for high-altitude use must be given a reduced voltage rating. Both sealed and derated components are used in the field. Pressure-sealing resilient rubber seals, grommets, and "O" rings are usually satisfactory for sealing components. Hermetic seals provide absolutely air-tight sealing by means of a glass-to-metal bond. In addition to providing sea-level performance at all altitudes, these are essential parts of hermetically sealed equipment.

Fig 9 illustrates and briefly describes a variety of sealing devices.

CORROSIVE ENVIRONMENTS

Such conditions as salt spray and salt-laden atmosphere are typical of sea coast environments, where a large number of electronic installations are located. Unless metallic surfaces such as the connector shells and contacts are protected by plating or a similar non-corrosive surface, rapid deterioration may occur.

A 50-hour salt spray test has traditionally been required for military equipment. This may give some idea of relative service life but is rather unreliable.

Fungus is a problem in hot, humid environment. Electrical parts that are nutrient are subject to deterioration by a large number of micro-organisms comprising fungi and bacteria. This usually takes the form of mildew and rot decay. Fungus growth can be quite easily eliminated by impregnating components with fungicides.

Sealed type connectors protect contact pins and sockets against corrosion. Dust caps protect exposed contacts when connectors are not mated.

EXTRA-TERRESTRIAL

With the experimental use of earth satellites and high-altitude rockets, environments outside the earth's atmosphere are beginning to be investigated. Some of the extra-terrestrial conditions which will be likely to pose problems for electrical equipment are ionized gases, meteoritic dust, ozone, ultra-violet rays, cosmic rays, and free electrons.

HEAT AND RADIATION ENVIRONMENTS

Nuclear power plants now being built require electrical connectors having long life in 1000F heat and intense nuclear radiation. In addition, moisture sealing is usually required since the connectors may have to operate in severe humidity. Connectors for these environments require thermal and radiation resistant materials. Wire at-

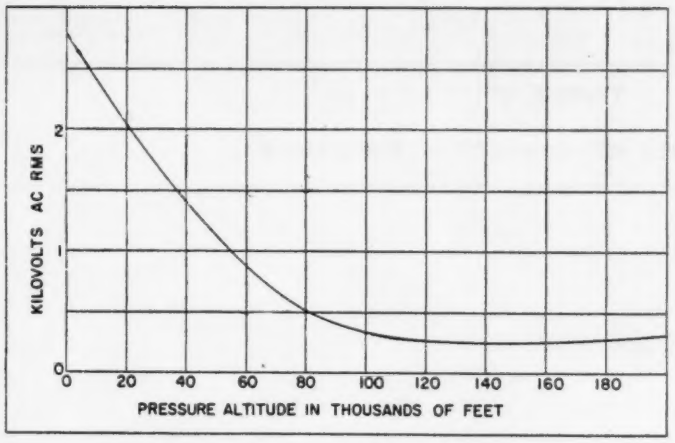


Fig. 8 Flashover versus altitude (pressure).

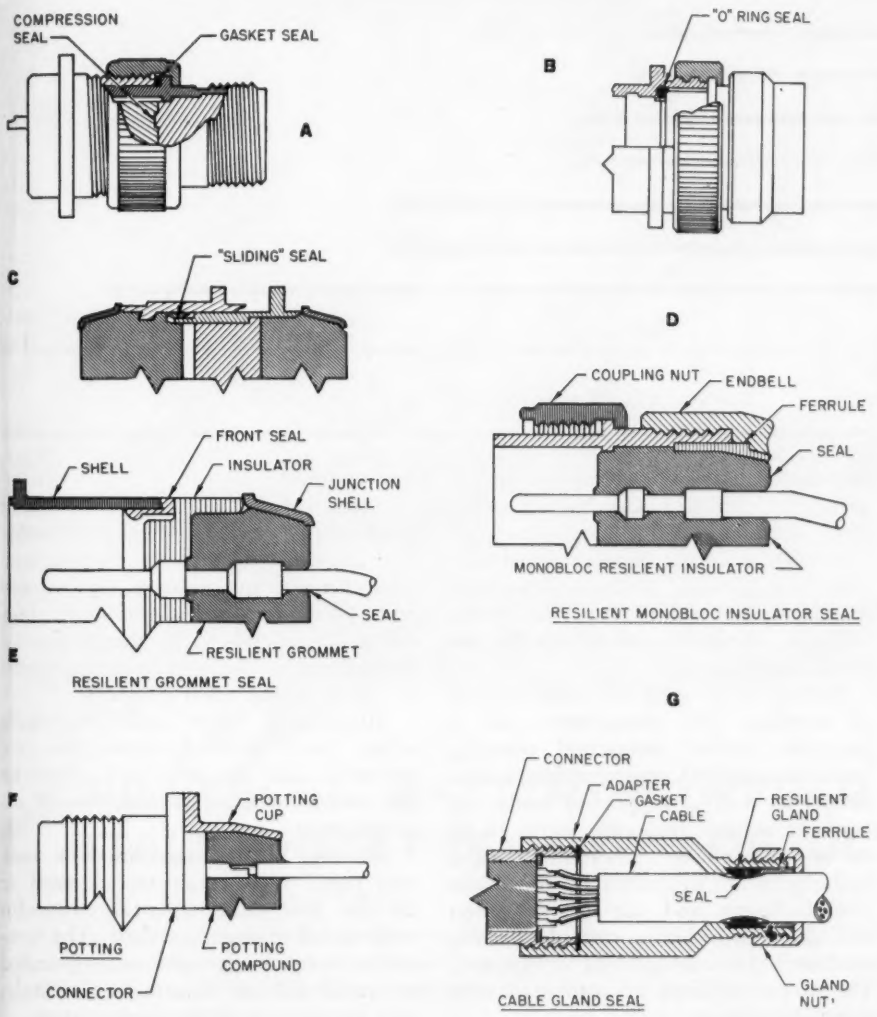


Fig. 9—Methods of sealing—front and back:

A Interfacial seal (compression seal) by interference fit of resilient insulators. Also a gasket seal under the coupling nut of the plug.

B "O" ring seal in the receptacle barrel.

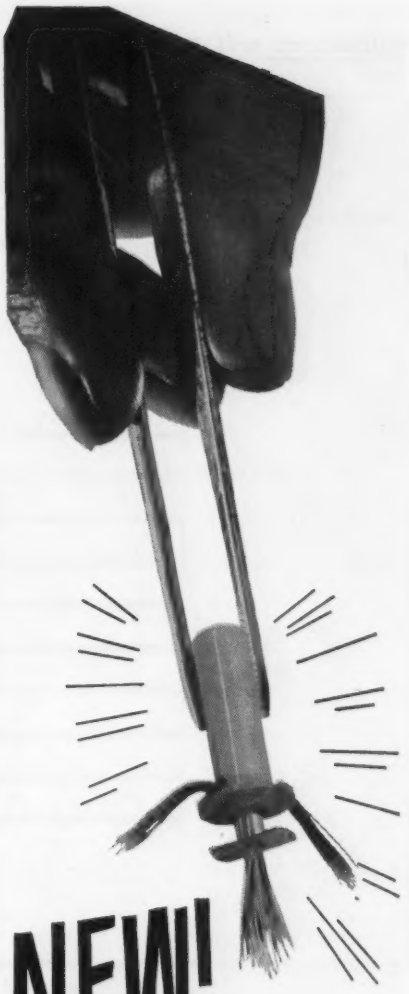
C Resilient insulator formed so as to provide a seal around the shell flange of the mating connector. This seal allows the mated connectors an axial sliding tolerance while still maintaining a seal.

D Monobloc resilient insulator. Clamping down of the endbell compresses and seals the wires by virtue of the tapered ferrule.

E Resilient grommet seal. This seal action is effected in the same way as the monobloc insulator (D).

F Potting method of sealing. The contacts are wired and then potting compound is applied which completely seals off the rear of the contacts.

G Sealing about the cable. The gland nut is tightened down which forces the ferrule to compress the resilient seal around the cable.



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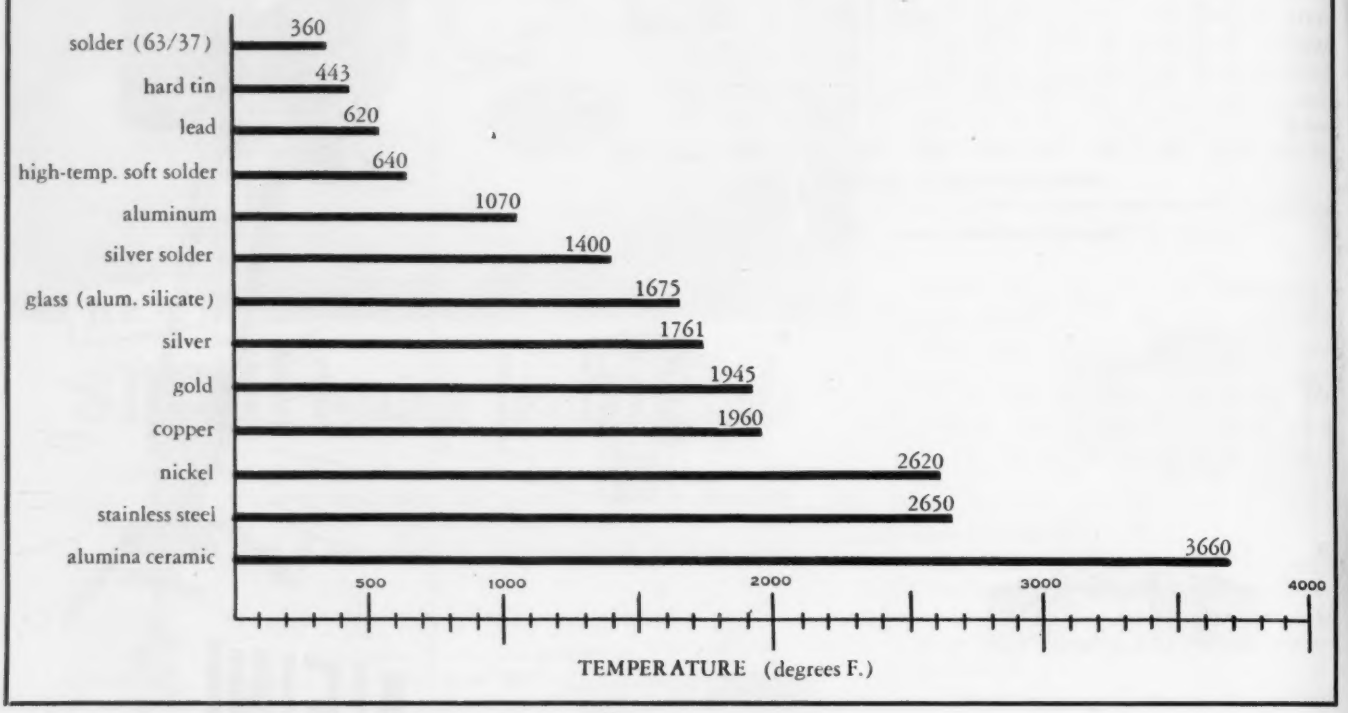
CIRCLE 39 ON INQUIRY CARD

TABLE V

MELTING POINTS OF CONNECTOR MATERIALS



taching techniques include high temperature soft-solder, silver solder, brazing or crimping of wires to contacts. Stainless steels, nickel alloys and ceramics are used for housing and insulators respectively; silver alloys serve as contacts. Cannon Electric has accomplished heat-resistant moisture sealing by means of mating ball and cone seats. Advance development work is under way on 1500F connectors.

For convenient reference, Table V charts the melting points of connector materials.

Reliability Factors

Soldering technique is an important factor in the reliability of an electrical connection. Excess solder may reduce effective contact spacing, increasing susceptibility to arcing, and weakening the conductors near the joints, with increased probability of developing a fault under vibration. Cold solder joints are obviously unsuitable, but may be very hard to detect visually. Only non corrosive solder should be used; an improper flux may lead to corroded contacts months after the soldering operation with possible costly consequences. The importance of correct soldering is emphasized by the major connector manufacturers who distribute extensive notes on recommended techniques. One manufacturer now offers prefilled solder cups such that when a lightly tinned wire of suitable size for the contact is inserted in the heated solder cup, the solder will not overflow or flow into the external strands.

Potting or covering the open sections of standard AN connectors with a pourable rubber compound provides protection against severe moisture conditions as well as support of leads and contacts where they are most likely to be affected by vibration. Potting techniques are described by the major manufacturers and are usable when the shell provides a suitable casting enclosure for the potting compound. Plastic potting cups are provided with some connectors.

RECENT DEVELOPMENTS AND APPLICATIONS

Custom cabling and wire harnesses terminated in electrical plugs are available from connector manufacturers to provide a more complete package, and to assure reliability by including assembly and connections in the purchased item. The manufacturer checks out the complete cabling assembly recommended for missile circuitry where more than usual ruggedness are required.

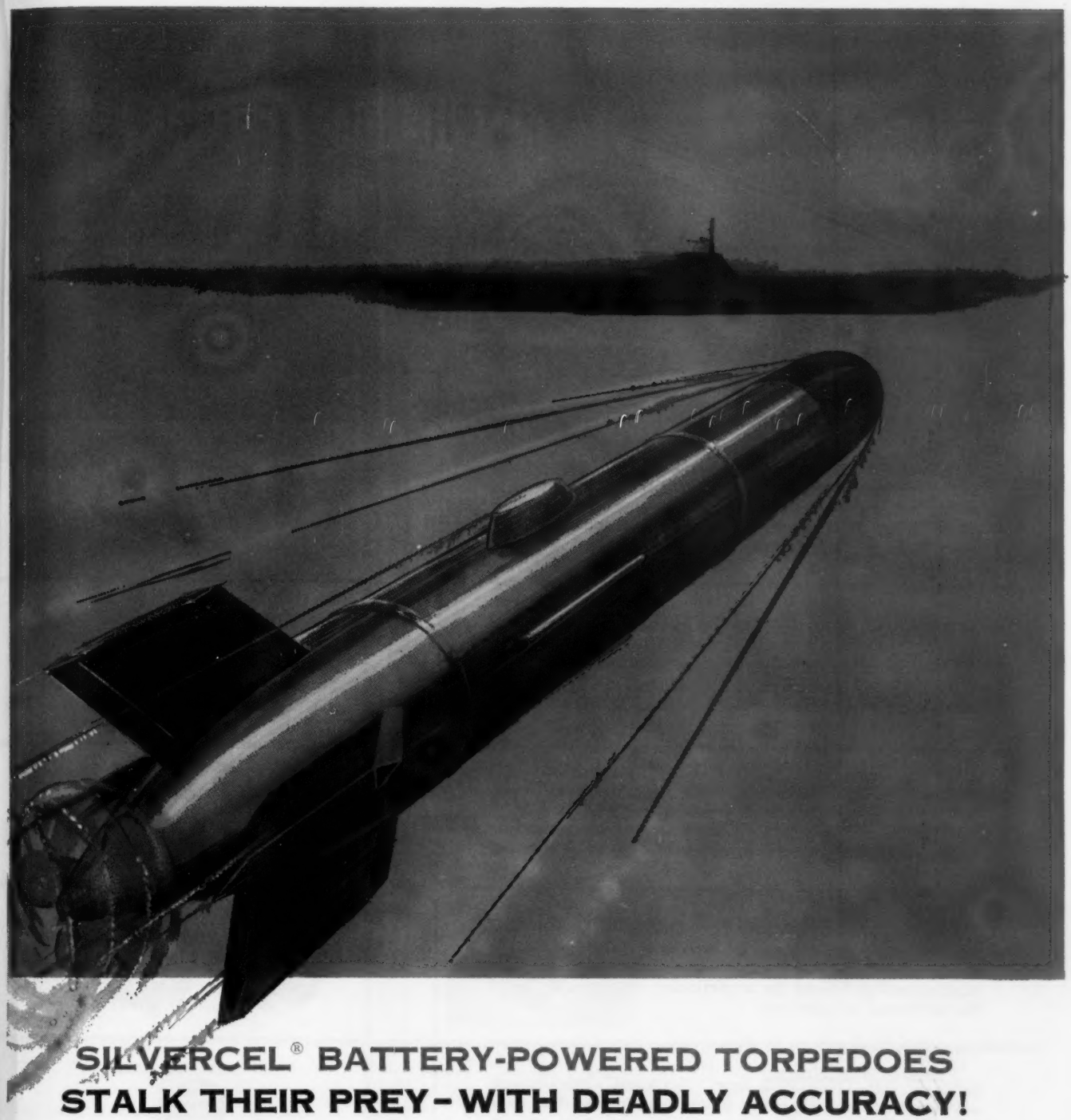
Cannon describes heavy-duty power connectors (3-phase, 4-wire, 575 volts, 150 amperes) including two extra contacts for connection to a control cirsuit. This provides for automatic shutoff of current when the plug is disconnected and prevents damaging circuit-breaking at the main contacts.

Mis-mating plug and receptacle when two identical connectors are mounted side by side may often be prevented by using reversed insert arrangements.

Cannon Electric announces a rack and panel type connector claimed to be the first environmental connector with an all-magnesium shell. The connector is extremely light weight, sealed to avoid voltage derating at altitude, and resistant to B-58 environment.

Thermocouple contact connectors are available for installations involving the use of thermocouples to measure heat. These must have contacts of exactly the same alloy as used in the thermocouples themselves. Common alloys include chromel, alumel, iron and constantin.

Wiggins manufactures a line of quick operate connectors for fluid and electrical connections. Mating receptacle and plug are coupled by pushing together until an audible click is heard, and are decoupled by pulling. Es-



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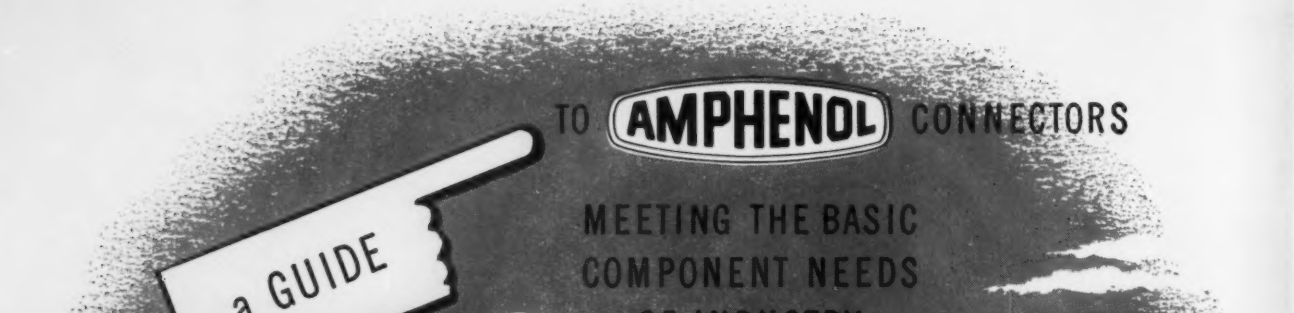
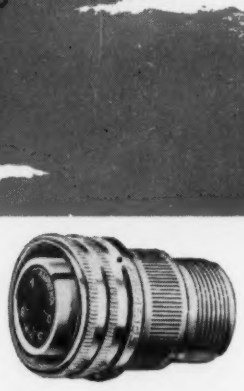
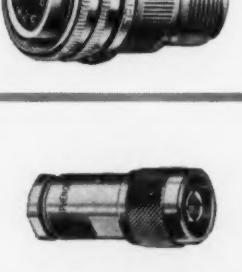


AN/MS CONNECTORS a complete selection of standard MIL-C-5015 connectors, including new "Stub E" environmentally resistant constructions. Miniature AN-type 165 series; miniature "Minni E" environmentally resistant connectors. Request Catalog A5 for complete data.

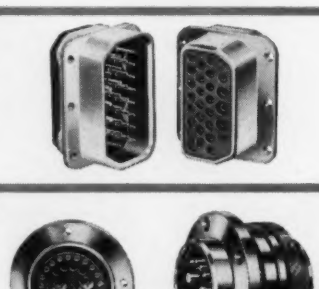


RF CONNECTORS every standard RF Series, N, BNC, C, HN, BN, LC, LT, UHF is available from AMPHENOL. Subminax RF connectors are an expanding line of subminiature types made only by AMPHENOL. Complete engineering services stand behind each AMPHENOL RF. Request Catalog D3.

RACK & PANEL CONNECTORS from the remarkable Blue Ribbon connectors with their smooth-working "ribbon" contacts to new "Poke Home" contact designs, AMPHENOL connectors meet every rack & panel application need. Request Catalog B6.



MISSILE CONNECTORS Breakaways, umbilical and interstage, are designed and produced by AMPHENOL for a large number of missile projects. Each is a special purpose connector, application-engineered for a particular requirement. Write for additional information.



HERMETIC SEAL CONNECTORS new "Identoseal" marking on AMPHENOL hermetically sealed connectors provides clear contact identification in the compression sealed glass inserts. Receptacles to mate with AN/MS, 165 and MinniE connectors. Headers also available. Request Catalog A5.

PRINTED CIRCUIT CONNECTORS 143 Series receptacles mate with standard .055" -.073" boards, 6 to 22 contacts, and with 133 Series plugs and adapters, 10 to 22 contacts. Superior gold-plated contacts, other reliability features. Request Catalog B6.

CABLE & WIRE PRODUCTS are important AMPHENOL components, also. Request Catalog W2.

amphenol connector division
amphenol cable & wire division
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AMPHENOL

CIRCLE 41 ON INQUIRY CARD

pecially useful in hard to get at areas, Wiggins' line is primarily highly specialized connectors and coupling devices for missiles and jet aircraft.

Deutsch announces a line of connectors featuring quick disconnect, and an exclusive ball lock coupling ring. Exceptionally fast attachment and disconnecting of leads by means of a novel crimping process and insert design. Silicone rubber inserts provide excellent sealing and perform over the temperature range of −100F to ±300F. Contacts are of the snap-in type. Construction features high crimp strength. The seal remains closed until complete disconnect is achieved to avoid sparking in explosive atmosphere.

BUYERS' GUIDE FOR CONNECTORS

The companies listed below in general provide a broad line of connectors of the type covered in this Components Digest. Manufacturers who specialize in connector types not included here will be listed in the July Components Digest which will continue our coverage of this topic.

Amphenol-Borg Electronics Corp.
1830 S. 54th Ave., Chicago, Ill.

Bendix Scintilla Div.
Sidney, N. Y.

Burndy Corp.
Conn. & Richards Ave., Norwalk, Conn.

Cannon Electric Co.
3208 Humboldt, L. A., Cal.

Cinch Mfg. Corp.
1028 S. Homan, Chicago, Ill.

Consolidated Electrodynamics Corp.
300 N. Sierra Madre Villa, Pasadena, Cal.

Continental Connector Corp.
34-63 56th St., Woodside, N. Y.

The Deutsch Co.
7000 Avalon Blvd., L. A., Cal.

Gorn Electric Co., Inc.
845 Main St., Stamford, Conn.

U. S. Components Inc.
454 E. 148th St., Bronx, N. Y.

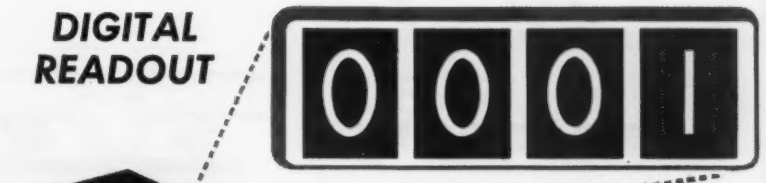
Winchester Electronics
Willard Rd., Norwalk, Conn.

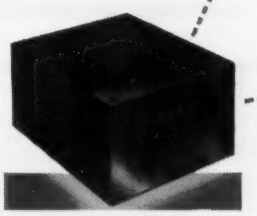
E. B. Wiggins Oil Tool Co., Inc.
3424 E. Olympic Blvd., L. A., Cal.

The NEW Series BH100

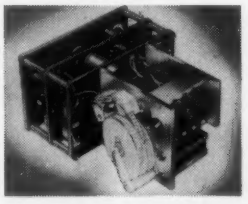
MILLI-V-METER*

DIGITAL READOUT

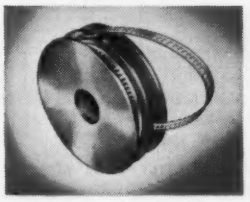




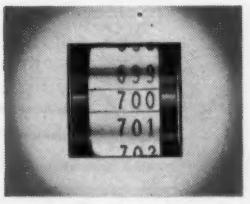
SMALL SIZE — This compact, transistorized, servo-driven instrument measures only 3 x 5 x 5¾".



ALL INCLUSIVE — With Zener reference, power supply, amplifier, servo motor, 144" tape-slidewire.



TAPE-SLIDEWIRE — Mounted on side-by-side spools, slidewire is embedded in edge of tape, punched for sprocket drive.



PRINTED READOUT—Calibration printed on tape available to measure steady-state conditions or where input deviates more than 13%.

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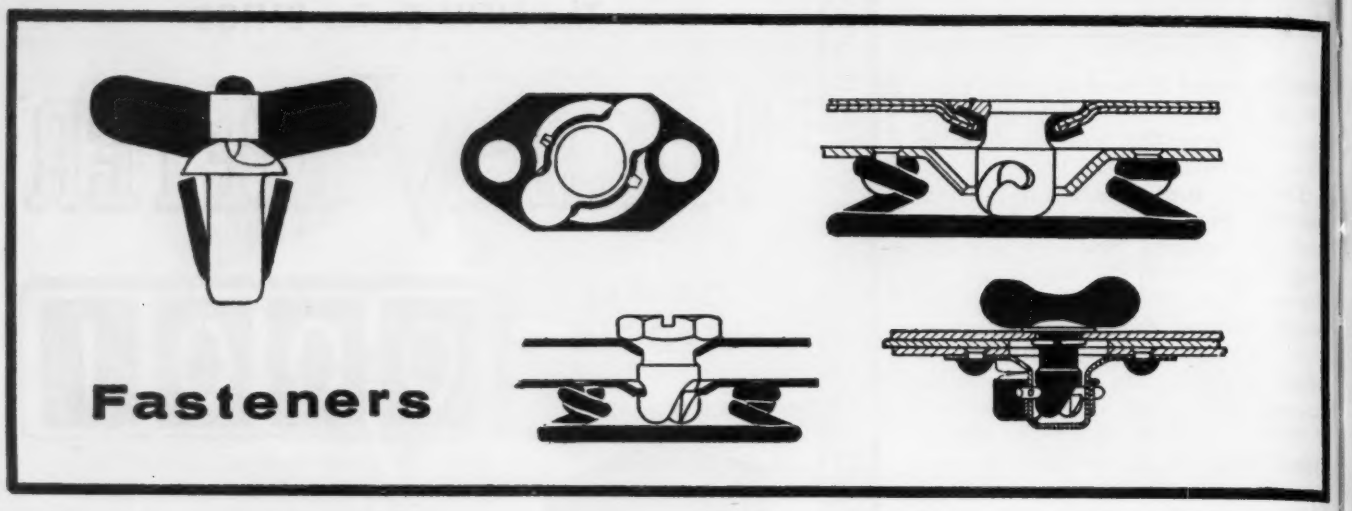


QUICK OPERATING FASTENERS

Increasing complexity of modern equipment and marked emphasis on flexibility and ease of maintenance have focused additional importance on selection and proper application of quick-operating fasteners. These fasteners are so widely applied in aircraft and industry that a good working knowledge of factors affecting their selection and use is important to design engineers. This Components Digest treats this topic in detail. By recoginizing the breadth of the field of fasteners as a whole, and by concentrating only on this limited portion, a detailed treatment becomes feasible. Many of the design and selection factors applicable to quick-operating fasteners may be applied to other types as well, a fact which will simplify consideration of other fastener types in future Components Digests.

This presentation is further narrowed to a consideration of principles, with only cursory reference to specific commercial types, since the latter information is thoroughly covered in two recently published reference works:

Fasteners Handbook by Julius Soled, Reinhold, 1957

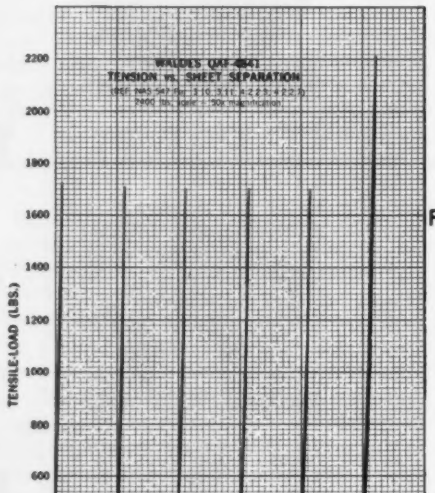
Handbook of Fastening and Joining of Metal Parts by Vallory H. Laughner, McGraw-Hill, 1956

Both these volumes are comprehensive. Soled's book is a compilation of commercially available fasteners with brief descriptions. A sectional breakdown classifies the main types of fasteners with one section devoted to "Quick Release Fasteners". Here a brief introduction is followed by a description of 17 specific fasteners. Each description includes: photograph or drawing, description, features, uses, standard materials, standard sizes, remarks, manufacturer.

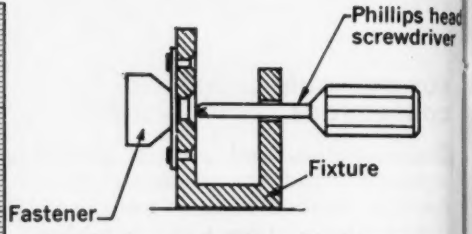
Laughner's book is more descriptive of principle with less emphasis on commercial varieties. The first section covers fundamentals of various fasteners and fastening techniques, with extensive information on standards. The treatment includes considerable evaluation and comparison information to assist in fastener selection.

In addition to these excellent books, articles have appeared in the engineering journals surveying the various types of fasteners and listing commercial varieties.

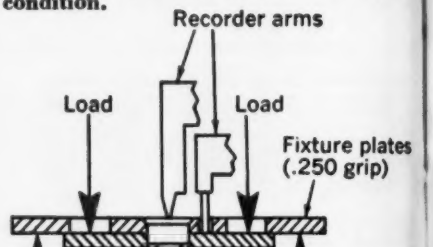
Because of the availability of this literature, our treatment here focuses on principles, selection factors, and a discussion of the more important specifications. The Buyers' Guide directs the reader to commercial sources.



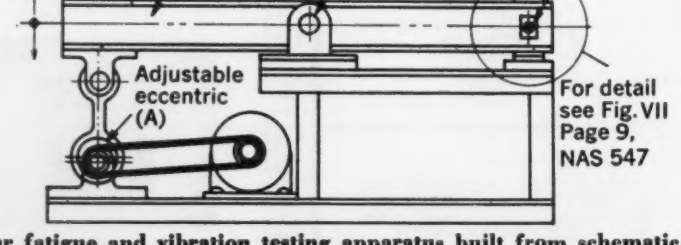
(c) Typical curves of sheet separation vs. tensile load taken on 5 samples.



(a) Endurance cycling. Each cycle consists of rotation from the completely disengaged position to the fully locked condition.



(b) Tensile testing fixture. Separation of sheets is measured under load.



(d) Shear fatigue and vibration testing apparatus built from schematic drawings on page 9 of NAS547.

Fig. 4—Set-ups for testing of quick-operating fasteners.

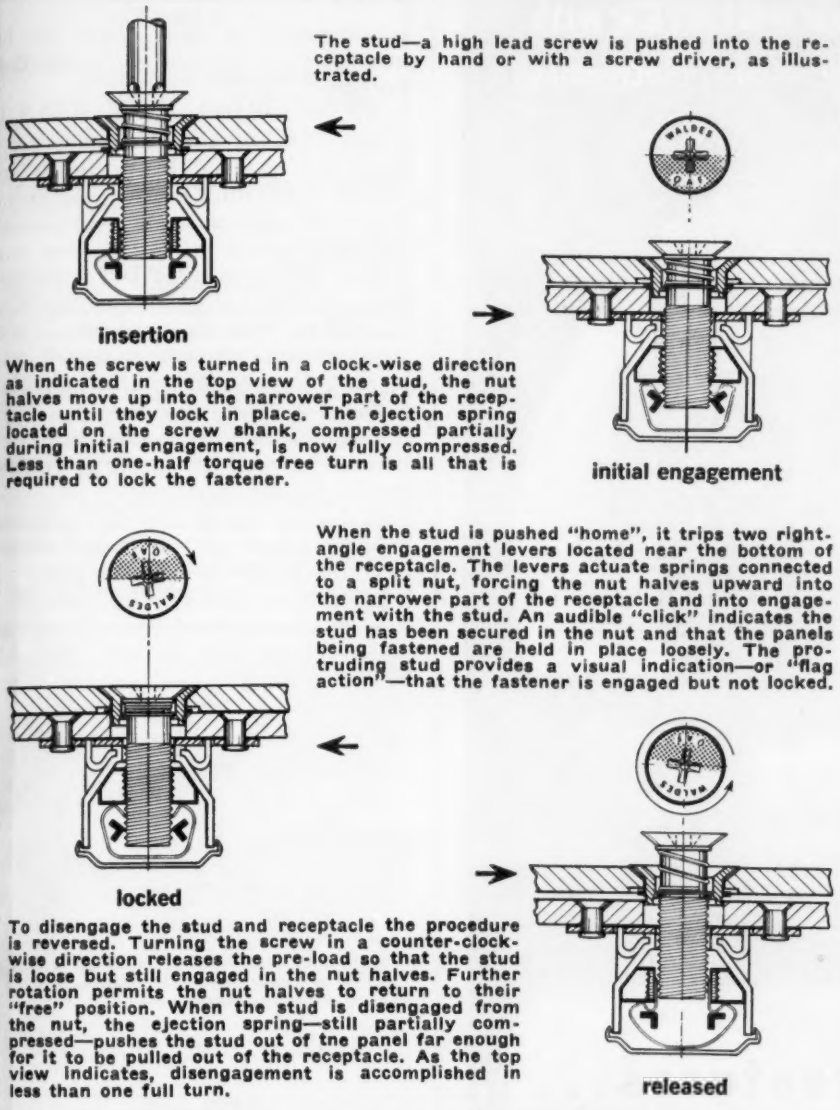

The stud—a high lead screw is pushed into the receptacle by hand or with a screw driver, as illustrated.
insertion
When the screw is turned in a clock-wise direction as indicated in the top view of the stud, the nut halves move up into the narrower part of the receptacle until they lock in place. The ejection spring located on the screw shank, compressed partially during initial engagement, is now fully compressed. Less than one-half torque free turn is all that is required to lock the fastener.
initial engagement
When the stud is pushed "home", it trips two right-angle engagement levers located near the bottom of the receptacle. The levers actuate springs connected to a split nut, forcing the nut halves upward into the narrower part of the receptacle and into engagement with the stud. An audible "click" indicates the stud has been secured in the nut and that the panels being fastened are held in place loosely. The protruding stud provides a visual indication—or "flag action"—that the fastener is engaged but not locked.
locked
To disengage the stud and receptacle the procedure is reversed. Turning the screw in a counter-clockwise direction releases the pre-load so that the stud is loose but still engaged in the nut halves. Further rotation permits the nut halves to return to their "free" position. When the stud is disengaged from the nut, the ejection spring—still partially compressed—pushes the stud out of tne panel far enough for it to be pulled out of the receptacle. As the top view indicates, disengagement is accomplished in less than one full turn.
released

Fig. 1—Operation of typical quarter-turn fastener. While this illustrates the product of a particular manufacturer, operation is similar to other varieties with different locking mechanisms.

APPLICATIONS

Quick operating fasteners are used to secure panels, cowlings, and doors to aircraft and mobile equipment. They are widely used on special purpose processing machinery which may require frequent shut-down and re-setting to different sizes, shapes, and types of items being processed. In the electronic industry, quick-operating fasteners are used in holding down "black-box" type sub-assemblies such as amplifiers and power supplies, and for fastening chasses, racks, and other major sections of electronic systems. Ease of servicing and rapid withdrawal and re-installation, as well as absolute reliability, are major selection factors.

The food industry, utilizing complex packaging machinery which must be readily adapted to different production batches with a minimum of down-time, makes extensive use of the quarter-turn fastener. Carrying containers which must be changed to suit different package sizes may require as many as one thousand fasteners in a large machine! In some types of production, changes are required several times a day. In such instances, the economic use of the machine can *depend* on quick-operating fasteners.

In liquid processing industries, pumps, valves, and similar flow elements may require frequent cleaning, either to eliminate residues, or to accommodate different flow products. Here, quick-operating fasteners play a key part.

There are many applications in which the frequency of locking and opening, rather than time saving suggest the specification of quick-operating fasteners. Frequent servicing, adjustment or routine periodic checking are especially simple where worn screw threads or the

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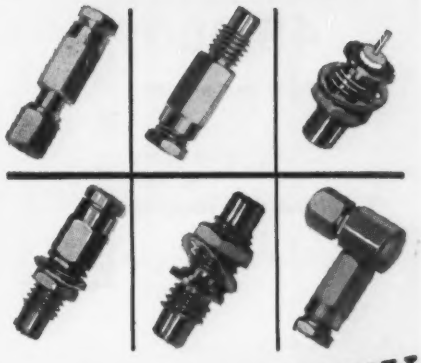

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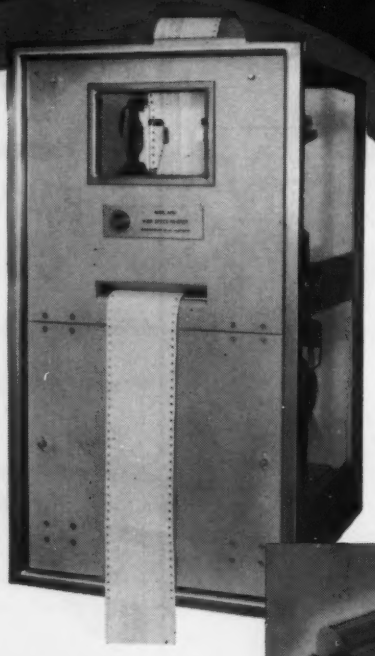

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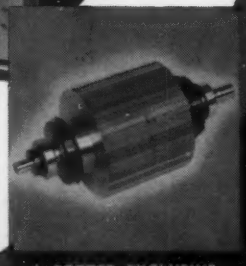

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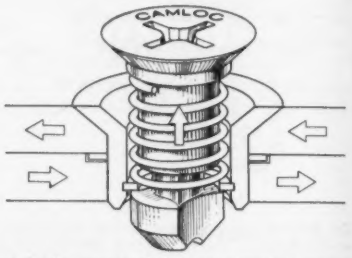
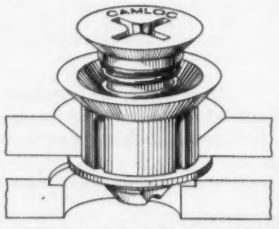
misplacement of small parts can be avoided by a suitable quick-operating fastener.

In the aircraft industry, these fasteners add little weight, simplify servicing and overhaul by providing access to important internal components, meet rigid environmental requirements including severe vibration, and are among the most reliable of components. Millions of quick-operating fasteners have been used, not only on the super-structure of modern aircraft, but in many less critical internal locations.

Quick-operating fasteners are used throughout industry, suiting many industrial as well as military requirements. Serious consideration of available fastener types, and the optimum application can result in a marked superiority in the overall suitability of a piece of machinery. Of course, the time to choose the fastener is in the design phase, and not after the de-



Shear loads, represented by horizontal arrows, are carried by bushing (blue section) leaving stud free to move upward under spring action.



Grooved bushing for retaining ring permits it to retract and allows maximum angle of approach to the frame.

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Fig. 2—Stud assembly showing how shear loads are carried. The stud assembly shown above engages a one-piece receptacle. The stud remains attached to the outer panel so that no parts can be lost. The design of the stud assembly permits small, uniformly spaced stud length increments. With other parts uniform, inventory requirements are minimized. A single stud may be removed without disturbing adjacent studs, to facilitate replacing a damaged or worn stud with the panel still attached. The receptacle is designed to provide uniform locking torque, a positive stop, and a detent for positive locking, even under extreme vibration. The locking of the stud pin in the detent can be both felt and heard. Grommets ars used with the stud assembly in the heavier series to protect the outer panel against abrasion.

TABLE I

QUICK-OPERATING FASTENERS, FEATURES AND SELECTION FACTORS

Tensile and shear load capacity adequate for application.
Automatic adjustment to sheet separation (no special adjustments to compensate for warpage, deformation, or thickness variations in the panels being secured)
Strip-proof construction—no cross-threading.
Visual indication—protruding stud and/or misalignment of screw driver slot indicating that parts are not locked.
Temperature resistance—strength at high temperature.
Corrosion resistance—salt spray, compatibility with unusual metals, particularly in missiles.
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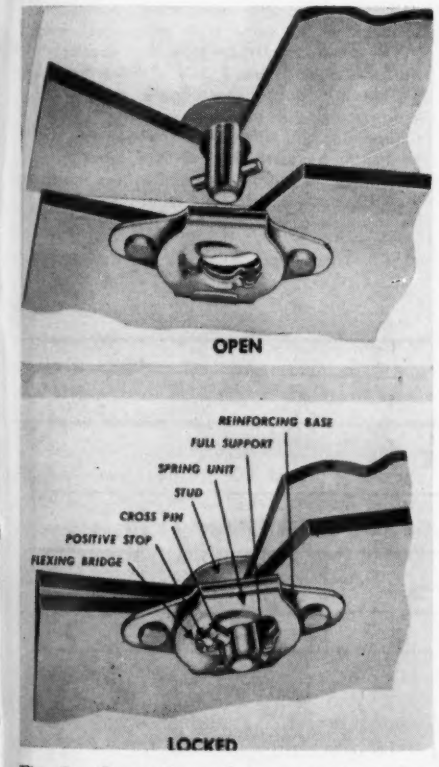


Fig. 3—Operation of a quarter-turn fastener by Fastex.

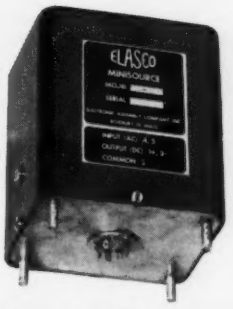
signs of most items have been frozen.

There have been many instances where special tooling and higher unit costs occurred because the selection of a suitable standard fastener had been delayed until it was too late.

QUARTER-TURN FASTENER

A quarter-turn fastener is a specialized type of quick-operating fastener consisting essentially of a spring loaded stud assembly used in conjunction with a receptable featuring a locking action

power supplies



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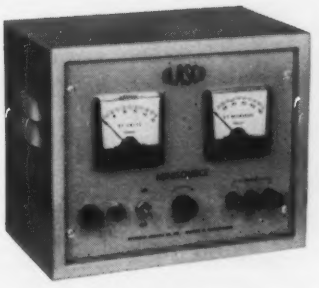

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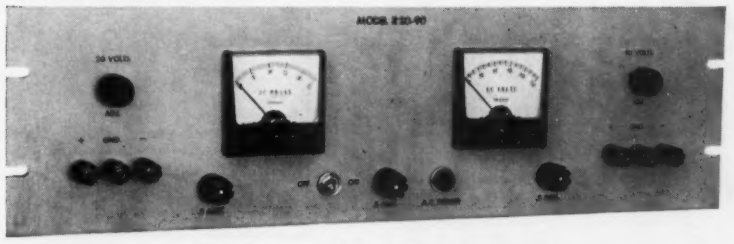

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TABLE II

CLASSIFICATION

as per MIL-F-5591A (ASG) Panel Fasteners

Type I—Flush head.
Type II—Oval head.
Type III—Wing head.

Class A—Floating receptacle.
Class B—Rigid receptacle.

Style 1—Type I for deep dimple, without grommet; Types II and III for undimpled sheet, without grommet.
Style 2—Type I for deep dimple, with grommet; Types II and III for undimpled sheet, with grommet.
Style 3—Type I for shallow dimple, with grommet; Types II and III for undimpled sheet, with grommet.

STYLE	SIZE	RIVET SPACING (inches)
1	7	1⅜
1	5	1
1	2	¾
2	—	—
3	7L (long)	1⅜
3	7S (short)	1
3	2	¾

A comprehensive table, amended in Oct. 1955, provides a complete listing of dimensions of the above styles, classes, sizes, and types.

Design Description from Specification

The style 1 fastener shall be of the stud-receptacle design such that when the fastener is opened, the stud assembly is retained by the outer panel and the receptacle is retained by the panel support. Styles 2 and 3 fasteners shall be of the stud-grommet receptacle design such that when the fastener is opened, the stud is retained in the panel. The grommet shall be designed to carry the stud load into the outer panel and to protect the outer panel from contact with the stud. The design of each style shall be such that the stud or stud-grommet combination and receptacle can be removed and replaced on the panel and supports with any other acceptable fastener of the same type, size, class, and style, without deviation from the applicable dimensions of figure 1 and without the use of special tools exceeding 2 pounds in weight. Styles 2 and 3 grommets shall be independently retained in the outer panel and shall be removable without damage to the panel. It is preferred that the receptacles consisting of more than one piece be supplied as preassembled units.

TABLE III

Mechanical Properties of MIL-F-5591A (ASG) Panel Fasteners

Size No.		2		5	7	
Style		1 and 2	3	1 and 2	1 and 2	3
Locking torque, minimum	lb in.	3.5	1.0	5.0	7.5	5.0
Locking torque, maximum	lb in.	8	11	12	18	20
Unlocking torque, minimum	lb in.	3.5	1.0	5.0	7.5	7.5
Unlocking torque, maximum	lb in.	10.4	12.5	15.6	23.4	25.5
Initial tension, minimum	lb	15	8	35	50	35
Rated tensile load	lb	200	200	500	700	700
Rated shear load	lb	200	200	500	700	700
Locking stop strength, minimum	lb in.	30	30	60	80	60
Vibration requirements						
Frequency	cpm ±100	3,600	3,600	3,600	3,600	3,600
Amplitude	inches	0.0625	0.0625	0.0625	0.0625	0.0625
Load	pounds	75	75	175	225	225
Endurance, minimum	cycles	5,000	5,000	25,000	40,000	40,000
Lateral movement of class A, Types I, II, and III Receptacle, minimum	inches	0.031	0.031	0.062	0.062[1]	0.062[1]

[1]*When receptacle with 1.000 inch rivet spacing is used, lateral movement may be 0.031 inch minimum.*

TABLE IV

NAS547 CLASSIFICATION OF QUICK OPERATING HIGH STRENGTH ROTARY FASTENERS

Type I—Flush Head
Type II—Protruding Head

Class A—550 degrees F
Class B—1000 degrees F

Size—#0—2720 lbs Ultimate Shear Load
Size—#1—4650 lbs Ultimate Shear Load
Size—#2—7300 lbs Ultimate Shear Load

to hold the rotative member in place under spring tension. Locking or unlocking requires a fraction of a turn. Fig. 1 shows the construction of a typical quarter-turn fastener, and how it is installed. Fig 2 shows the stud assembly of a second type. During locking, the stud is depressed against the stud spring until proper engagement of cross-pin and the cam-locking surface of the receptacle (not shown) is achieved. A quarter turn of the stud is then sufficient to lock the assembly. Because of the spring loaded stud, some axial pressure is required while turning. The heads are generally provided with means for turning, such as a screwdriver slot, knurl, wing-shaped projection, etc. In the released position, the stud is ejected by the stud spring. Fig. 3 illustrates a third design.

The quarter-turn fastener is distinguished by a number of features which make its use especially desirable to project engineers. Some of these features, together with selection factors, are listed in Table I.

STANDARD FASTENERS

Quick release fasteners for panels are covered by Military Specification MIL-F-5591A (ASG) 2 October 1953. Table II is a concise description of the method of classification as covered by the specification including a brief design description extracted from the specification. The military specification provides at least a measure of standardization of quick release fasteners. Table III lists some of the important mechanical properties of the panel fastener which constitute the basis for qualification testing. The specification includes a table of dimensions for all types, classes, styles, and sizes of standard fasteners. QPL-5591-2 31 March 1954, Military Qualified Products List of Products Qualified Under Military

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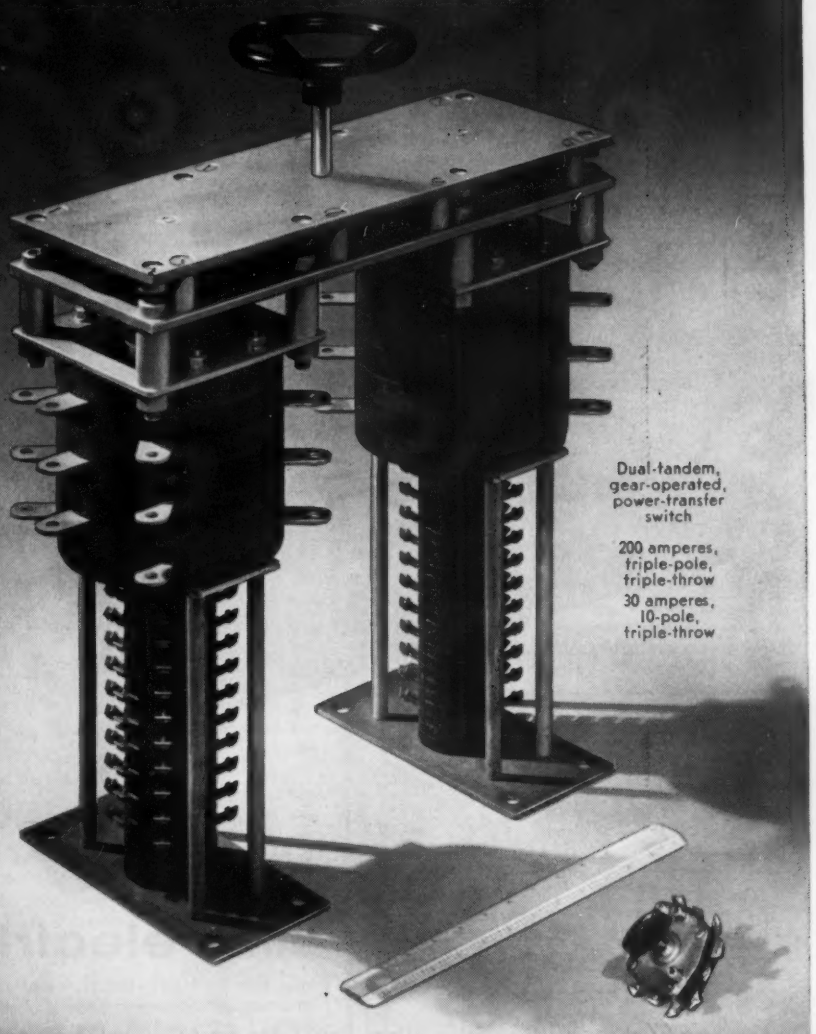

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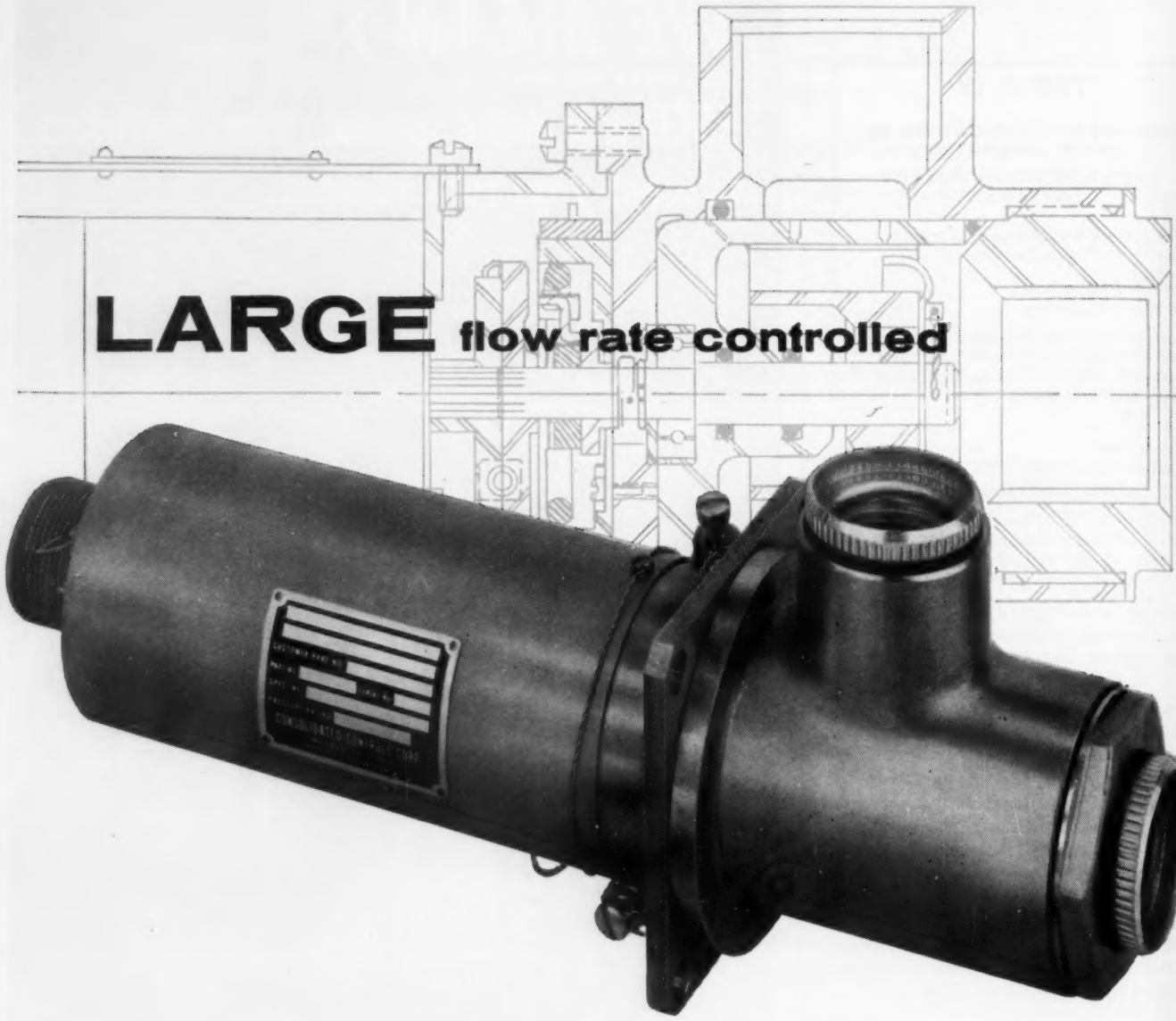

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TABLE V

NAS 547, ROOM TEMPERATURE MECHANICAL PROPERTIES

Size Number	No. 0	No. 1	No. 2
Locking Torque	20 in-lbs (Max)	30 in-lbs (Max)	40 in-lbs (Max)
Unlocking Torque	25 in-lbs (Max)	35 in-lbs (Max)	45 in-lbs (Max)
Torque Out	60 in-lbs (Min)	100 in-lbs (Min)	160 in-lbs (Min)
Ultimate Shear Load	2720 lbs (Min)	4650 lbs (Min)	7300 lbs (Min)
Rated Shear Load	2080 lbs (Min)	3580 lbs (Min)	5620 lbs (Min)
Ultimate Tensile Load	1290 lbs (Min)	2210 lbs (Min)	3470 lbs (Min)
Rated Tensile Load	990 lbs (Min)	1700 lbs (Min)	2660 lbs (Min)
Sheet Separation (Test Condition)	Not to exceed 0.005 in. at rated tensile load	Not to exceed 0.005 in. at rated tensile load	Not to exceed 0.005 in. at rated tensile load
Sheet Pull-Up	1/16 in (Min)	1/16 in (Min)	1/16 in (Min)
Stud Push-Out	150 lbs (Min)	200 lbs (Min)	250 lbs (Min)
Receptacle Push-Out	100 lbs (Min)	125 lbs (Min)	125 lbs (Min)

TABLE VI

Condensed Description of Important Performance Factors Covered By NAS547

Locking and Unlocking Torque—The maximum locking torque value listed in Table V shall not be exceeded while operating the fastener through the entire range of sheet pull-up from initial engagement to the fully locked condition. The unlocking torque value listed shall not be exceeded while rotating the fastener from the fully locked condition to the point of complete disengagement.

Torque-Out—When the installed fastener is subjected to the torque-out values listed in Table V there shall be no failure or permanent deformation visible to the unaided eye to any of the fastener components.

Shear—The fastener shall not develop permanent deformation visible to the unaided eye when subjected to the rated shear load and shall withstand the ultimate shear load specified in Table V without failure.

Tension—The fastener shall not develop permanent deformation visible to the unaided eye when subjected to the rated tensile load and shall withstand the ultimate tensile load specified in Table V without failure.

Sheet Separation—The sheet separation shall not exceed the value listed in Table V when the installed fastener assembly in the fully locked condition is subjected to the rated tensile load listed in Table V.

Sheet Pull-Up—The installed fastener shall be capable of initial engagement when a sheet separation condition exists at the fastener of not less than the values listed for "sheet pull-up" in Table V. The fastener shall then be capable of drawing the sheets together at the fastener to the fully locked condition.

Stud Push-Out—The stud assembly of the installed fastener shall withstand the push-out values listed in Table V without visible permanent deformation to any components or separation from the sheet.

Receptacle Push-out—The push-out test load shall be applied axially to the receptacle body through a stud of the type fastener being tested and sufficiently long to transmit the entire test load to the receptacle components.

Vibration—There shall be no fastener failure nor more than a 10% reduction in the torque required to tighten the locked fastener assembly.

Shear Fatigue—There shall be no single fastener failure of the fastener assemblies. At the conclusion of this test, the specimens shall be capable of meeting the other performance requirements of this specification.

Corrosion Resistance—The installed fasteners shall be subjected to salt spray in accordance with specification QQ-M-151 for 192 hours and inspected for corrosion. Fasteners shall not be rendered inoperable by this test.

Elevated Temperatures—The installed fastener assembly shall withstand the temperature limit specified for its class without being rendered incapable of meeting the performance requirements of this specification.

Endurance—The fastener shall withstand 2500 cycles of locking and unlocking without being rendered incapable of meeting the performance requirements of this specification.

Failure—A failure as defined by this specification will be considered to exist when any of the fastener component parts fracture or break, or where distortion, permanent set, or wear is of a degree which prevents the fastener from sustaining the applicable test load.

Workmanship—Workmanship shall be in accordance with high grade aircraft manufacturing practices. Fastener parts shall be free from burrs, tool marks, cracks and other defects which might affect their serviceability or performance as defined by this specification.

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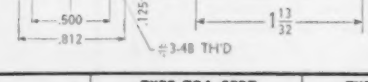

	TYPE TQA SPDT		TYPE TQA DPDT	
COIL RESIST. OHMS	OPERATE MA. DC	RELEASE MA. DC	OPERATE MA. DC	RELEASE MA. DC
50	20	7.0	28	10
100	14	5.0	20	7.0
200	10	3.5	14	5.0
500	6.3	2.3	9.0	3.1
1,000	4.5	1.5	6.3	2.3
2,500	2.8	1.0	4.0	1.4
5,000	2.0	0.7	2.8	1.0
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Specification MIL-F-5591 (ASG) lists qualified manufacturers on each of the types of standard fastener. While military requirements very often lay a foundation on which a manufacturer may develop a line of standard quarter-turn panel fasteners, the actual line may include a variety originally designed for industrial applications.

Standard fasteners by the leading manufacturers are sufficiently varied to meet the widest range of requirements. While more expensive than conventional screw-type fasteners, the higher cost of properly applied quick-release fasteners is amply repaid in terms of reliability and performance, and often intangibles, by such factors as improved product appearance. The key to successful application lies in recognition of the fastener problem at an early stage of the design. Tooling expense and production delays in the design and manufacture of special types are usually the result of waiting too long before checking the fastener.

NATIONAL AIRCRAFT STANDARDS COMMITTEE

In 1954 the National Aircraft Standards Committee compiled a specification NAS547 on quick operating, high strength rotary fasteners. This specification, revised in 1956, is widely recognized by users and manufacturers of this type device, although few fasteners fully meet the requirements.

The fasteners covered by this specification are classified in Table IV. Further definition is provided by the "Design" paragraph quoted here from the specification.

"The fastener shall be of the stud-receptacle design and shall be so constructed that neither the stud assembly nor the receptacle assembly can be inadvertently disassembled during normal operation. The design shall be such that the stud and receptacle can be removed and replaced in service with any other receptacle fastener of the same type, class, and size without deviations from the dimensions noted herein and without use of special tools. The fastener shall provide for retention of the stud in the outer sheet when unfastened."

Table V summarizes the important mechanical requirements while Table VI lists the more important performance factors covered by the specification. This latter tabulation should acquaint the design engineer with specific application factors in specifying this type component. Fig 4 shows some of the test methods for fastener evaluation.

BUYERS' GUIDE FOR QUICK OPERATING FASTENERS

This list includes only those fastener manufacturers whose products relate directly to the Components Digest coverage. The July issue will continue the coverage to include other fastener types.

AIRCRAFT RADIO Corp.
Boonton, N. J.
Positive locking, snap action, finger operated slide fastener.

AIRTRON—Div. of Litton
Morris Plains, N. J.
Quick disconnect fixtures for rigid and flexible waveguides,

CALENOY DIV., Illinois Tool Works
Hawthorne, Cal.
Two piece quarter-turn fastener.

CAMLOC FASTENER Corp.
22 Spring Valley Rd., Paramus, N. J.
Quarter-turn fasteners, latches, electronic chassis latch.

DIMCO-GRAY Co.
207 E. Sixth St., Dayton, Ohio
Positive locking, snap action finger operated slide fasteners.

DZUS FASTENER CO., Inc.
Box 185, Babylon, N. Y.
Quarter-turn spiral cam panel fasteners.

ELASTIC STOP NUT Corp.
2330 Vauxhall Rd., Union, N. J.
Two piece quarter-turn fastener.

FASTEX DIV., Illinois Tool Works
195 Algonquin Rd., Des Plaines, Ill.
Quarter-turn quick release panel fasteners.

HARTWELL CO.
9035 Venice Blvd., L. A., Cal.
Latches and hinges, rotary latches, trigger-action latches, marine latches.

MONADNOCK MILLS
1977 First Ave., San Leandro, Cal.
High strength quick release fasteners, quarter-turn fasteners, stud with nylon pressure sealing ring.

PATUSHIN AVIATION Corp.
5661 W. Century Blvd., L. A., Cal.
Two piece quarter-turn fastener.

SCOVILL MFG. Co.
99 Mill St., Waterbury, Conn.
Quarter-turn quick release panel fastener, wide variety of sizes and accessories.

SHAKEPROOF DIV., Illinois Tool Works
St. Charles Rd., Elgin, Ill.
Quick release fastener for high stress loading.

SIMMONDS AEROCESSORIES, Inc.
Tarrytown, N. Y.
Large variety of quick-operating, general purpose high strength latches, large variety of housing and fitting assemblies which may be combined interchangeably to suit specific application.

SOUTHCO Div. South Chester Fasteners
Lester, Penna.
Quick release, adjustable pawl, latches, quarter-turn fasteners.

VIBREX FASTENER Corp.
Mt. Kisco, N. Y.
Half-turn quick release fastener including rubber sleeve for vibration and noise isolation and sealing.

WALDES KOHINOOR, Inc.
47-16 Austel Pl., L. I. C., N. Y.
Quick operating stressed panel fasteners.

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For Your 3-Ring Binder

NEW DATA SHEETS

For your free copy of the data sheets listed on this page, circle the appropriate number of the item on the Inquiry Card.

PITCH SENSITIVITY VELOCITY PROBE

A new cylindrical probe, made in sizes as small as ⅛ inch measure total pressure, static pressure and yaw angle at any point in an air stream. It is supplied with its own calibration curve and is insensitive to pitch angle up to 15 degrees from normal to the axis of the probe. It is useful chiefly in measuring the velocity and flow directions in liquids or gases in such applications as pumps and turbines. United Sensor & Control Corp., Glastonbury, Conn. Circle 219.

MICA ISOLATORS

8-page data sheet K-5 contains 29 outline drawings of mica wafer shapes available without tooling costs, and describes how transistor reliability is increased when low cost mica wafers are used as isolators in heat sink applications. Magnetic Shield Div., Perfection Mica Co., Chicago, Ill. Circle 172.

SILICON BRIDGE RECTIFIERS

Miniature silicon bridge rectifiers for the replacement of bulky vacuum tube units occupy only 1/10 of the volume and weigh less than 1/60 of equivalent tube circuitry. These units measure 1.22 x 1.03 x .750" and weigh ½ oz. Designed primarily to prove extreme miniaturization in missile, airborne and ground system circuitry, they may be operated at temperatures up to 165C. Internat'l Rectifier Corp., El Segundo, Cal. Circle 201.

NEW SILICON RECTIFIERS

Silicon a-c to d-c power rectifiers, designed for intermediate power applications offer economy of extra-long operation, even under strenuous conditions. Rectification efficiency is demonstrated by maximum forward voltage drop, 1.2v at 10 amps, 27C. Syntron Co., Homer City, Pa. Circle 218.

LOW LEVEL DC AMPLIFIER

High temperature (100C) completely solid state DC instrumentation amplifier handles typical low level strain gauge and thermocouple inputs. Data sheet lists balanced input, integral supply voltage regulator, transistorized chopper, and environmental characteristics suited to extreme flight environments. United Electrodynamics, Pasadena, Cal. Circle 216.

NEW COMPONENTS

Lear has added a new line of flexible drive shafts, valve assembly, pressure regulators and differential pressure transducers. Lear, Inc., Grand Rapids, Michigan. Circle 182.

HIGH TEMPERATURE WIRE

Elaborate 64-page publication contains 8 sections of the latest engineering information and prices on high-temperature magnet wire, lead wire, cables, tubing, and Teflon tape. Information is consistent from section to section facilitating quick, easy reference on military specifications, temperature ranges, wire and cable constructions, colors and tests. Provides engineers with design criteria for high temperature wiring. American-Super-Temperature Wires, Inc., Winooski, Vermont. Circle 213.

TEMPERATURE CONTROLS

A new 8-page booklet describes Thermoswitch controls, mounting wells, with an explanation of how the units operate on the differential expansion of metals, complete operating specifications and dimensions, and available modifications and special features. Fenwal, Inc., Ashland, Mass. Circle 189.

MINIATURE MICA CAPACITORS

Six-page folder fully describes smallest mica capacitors for extreme miniaturized designs and printed circuit wiring. Specifications include blue-print drawings of units with crimped leads or straight leads; full capacity vs. dimensions, capacity and voltage ranges tables, plus temperature coefficient and capacitance drift limit charts. Electro Motive Manufacturing Co., Willimantic, Conn. Circle 176.

SINGLE-DECADE COUNTING UNITS

Construction and electrical data, auxiliary contacts and executions which make possible the use of single-decade counters in the solution of a wide variety of counting, telemetry and automation problems are described in new bulletin. Landis & Gyr, Inc., New York, New York. Circle 214.

ESCAPEMENT MECHANISM

New time-saving Escapement Mechanism increases connected series coil production up to 50%. Includes full technical details on types and sizes of coils wound, wire sizes, tension equipment, gears, cams, winding speeds, setup time, self-resetting automatic counter and brake. Geo. Stevens Mfg. Co., Inc., Chicago, Ill. Circle 193.

MICRO PROBE LITERATURE LIST

A literature list on micro probe research tabulates 73 articles which have appeared in domestic and foreign publications. Instruments Div., Philips Electronics, Inc., Mount Vernon, N. Y. Circle 220.

MINIATURE INDUCTORS

A new range of miniature toroidal inductors—from 1 millihenry to 3 henries—with a useful frequency range of from 10 kilocycles per second to 500 kilocycles per second, are now available. Designated as series 783, units measure 1" dia. x ½" high. Weight is only 0.5 ounce; fully encapsulated and hermetically sealed, for maximum resistance to high temperature and extreme shock. Arnold Magnetics Corp., L. A., Circle 170.

GROUND-STATION SUBCARRIER OSCILLATORS

Adjustable and servicable voltage-controlled FM subcarrier oscillators cover ground-station telephone, radio, or microwave data-transmitting applications. Oscillators plug readily into a transmitting multiplexer with conventional 9-pin octal connectors. Prototypes have operated for continuous months with an outage time of less than one minute. Tubes are mounted externally to dissipate heat, yet overall size is 4⅞ x 3⅞ x 1⅝. Modulation and line-frequency can be adjusted manually with accessible knobs. Filament power can be either AC or DC. Input is ±2.5 volts into 500 K ohms, and output is 3 volts at 5 K ohms, from low pass output filter. Linearity is ±.75% of bandwidth, and harmonic distortion does not exceed .5%. The Geotechnical Corp., Garland, Texas. Circle 166.

SLIP RING ASSEMBLIES

A new data file on various types of slip ring assemblies includes a description of general purpose units which have wide-range application and considerable variation in size, and gives a similar description of power slip rings. Also contains illustrated data on radio frequency and video, high voltage, high speed instrumentation, and power pulse slip ring assemblies. Engelhard Industries, Inc., Newark, N. J. Circle 177.

R.B. Carroll, Asst. Dir.
The University of Michigan
Ann Arbor, Michigan